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THE VIRGINIA JOURNAL OF SCIENCE

VOL. I, NEW SERIES No. 1

The Scale of the Universe

HAROLD L. ALDEN
University of Virginia

Man's activities have always been dependent upon astronomical phenomena. The daily rising and setting of the sun, recurrent phases of the moon, and the succession of the seasons have governed his life. This intimate relationship is reflected in the manner in which astronomical lore has found its way into his mythology, his literature, and his religious teaching and practices. It has given rise to the pseudo-science of astrology which assumes that, in some inexplicable fashion, the relative positions of the heavenly bodies influence human character and actions. It cannot be too strongly emphasized that astrological concepts have never been submitted to the test of controlled experiment or statistical techniques capable of testing their validity. The public is still exposed to the wiles of those unscrupulous enough to prey upon the credulity and gullibility of the ignorant.

In this technological age we are less conscious of our dependence upon the stars, though observations of them are still necessary to set our clocks to provide the split-second timing required by the pace of modern life, to regulate our calendar, and to navigate the seas and the air. Thomas Jefferson computed his own tables of the longitude of the sun. No one need do this today except as a mathematical exercise. Our clocks are set my means of radio signals or are accurately controlled by the revolutions of a distant dynamo. The sun dial is relegated to the status of a mere garden ornament.

The aim of any science is to answer the questions which the innate curiosity of the human mind raises within its particular province. Astronomy offers the greatest scope for such questionings. We wish to know what the celestial bodies are, where they are, how they came to be, and their ultimate destiny. Most important of all is the question of man's relation to the universe of which he is such an infinitesimal part. It is impossible to outline here the answers which astronomy gives at the present time to all these questions. Therefore I have chosen to limit myself to the 'where-ness' of the objects we see in the sky and to deal

[1] **Editor's Note:** In conforming with a policy established by the Editorial Board to present in the first three numbers of each Volume of the Journal an article of general interest and progress in the several fields of science, we have invited Professor Harold L. Alden, Director of the Leander McCormick Observatory at the University of Virginia, to contribute this article from the field of Astronomy.

mainly with the scale of the universe within the present range of our telescopes.

This choice of subject will serve to illustrate the methods by which science advances. While the scene is laid largely in the last half century, the beginnings are lost in the mists of antiquity. The present is built on the patient and painstaking work of past ages. Consideration of the scale of the universe will exemplify the leap-frogging of theory and observation, as further progress awaits the perfection of new tools or techniques capable of testing existing hypotheses or suggesting new avenues for exploration. Accidental discoveries made along the way may prove to be as significant as the main objective.

Science usually starts out with practical ends in view. As knowledge advances, the boundaries are pushed farther and farther beyond the limits of the immediately useful, into areas which appear to provide only intellectual satisfaction, but which may eventually prove of vital importance. When helium was first discovered in the spectrum of the sun, who could have foreseen the variety of its present uses? Who can predict to what extent the pure science of today will become the applied science of tomorrow?

Our knowledge of the scale of the universe has progressed through four principal stages which will be considered in their chronological order. These are (A) the size and shape of the earth, (B) the distance of the sun, (C) the distances of the stars, and finally, (D) the establishment of criteria by which our scale can be extended to the limits of our visible or photographable universe.

A. THE SIZE AND SHAPE OF THE EARTH

Early astronomers were limited to observations of the apparent brightness, positions, and motions of the heavenly bodies. Such instruments as they had were merely crude pointers. It is not known when systematic records were first kept, but they must have been in existence for many centuries before the Christian era. By the seventh century B.C. the Greeks already knew the obliquity of the ecliptic (the angle between the plane of the earth's equator and that of its orbit), the precession of the equinoxes (the motion of the earth's pole of rotation among the stars), and the recurrence of eclipses in the period known as Saros. While they added little in the way of observations, the Greek philosophers brought their special genius for speculation to bear on the probable causes of the observed phenomena.

By analogy with the sun and the moon, the concept of the earth as a circular disc must have appeared at an early date. The probability of its being a sphere was supported by Aristotle, who advanced some of the arguments still regarded as convincing and others that appear quite fantastic. The first attempt to apply geometrical methods to the actual

determination of the size of the earth is usually credited to Eratosthenes about the middle of the third century B.C. He noted that the difference in the meridian altitudes of the sun at Alexandria and Syene was about one-fiftieth of a circle and rightly ascribed this to the curvature of the earth's surface. He measured the distance between the two places as 5,000 stadia, giving 250,000 stadia for the circumference of the earth. Unfortunately the precise value of the stadium is not known, but it is possible that Eratosthenes was remarkably close to the truth. His method was sound and is the same as that employed since, using stars instead of the sun to determine angles subtended on the celestial sphere by arcs on the earth's surface which can be accurately measured.

While sporadic measures of the length of a degree were made from time to time, no real contribution to the exact size of the earth was forthcoming until interest in the problem was revived nearly two thousand years later. The invention of the telescope provided better means for measuring the angles and more accurate methods had been devised for measuring the distances. The first really useful measures date from the middle of the 17th century. About the same time it was found from variations in gravity that the figure of the earth was not a sphere but an oblate spheroid as a consequence of its rotation on its axis. This discovery led to the measurement of arcs at various latitudes, as well as determinations of the force of gravity, and stimulated the mathematical study of the figure of the earth. Ancient astronomers had realized that a rotation of the earth would provide a simpler explanation of the apparent motions of the heavenly bodies than their complicated system of cycles and epicycles. The possibility was rejected however on the ground that the resulting centrifugal force would throw all loose objects off the terrestrial sphere. As soon as the law of gravitation was formulated, this objection was removed and the rotation became a generally accepted fact.

The regular spheroid which most nearly fits the sea-level surface of the earth is due to Hayford, who published in 1909 a discussion of all available geodetic measures. He found for the equatorial radius of the earth 3963.34 miles and for the polar radius 3949.99 miles. The polar radius is thus shorter than the equatorial by one part in 297. This is confirmed by the gravity measures and by dynamical effects which result from the flattening.

The knowledge of the exact size and shape of the earth is of fundamental importance because all other measures in the universe depend upon it. The earth provides the only base line accessible for direct measurement. While relative distances in space can be determined with more or less accuracy, their conversion into miles or kilometers is entirely dependent upon the relation of our units to the radius of the earth at the point where the observations are made or to the exact distance between

observers on different parts of the earth. Any error in the base line is multiplied by a factor of 23,500 by the time we reach the sun. Since the nearest star is more than 275,000 times as far away as the sun, the error in its distance will be over 6,000,000,000 times the error in our base line, even though the angular measures from the ends of that base line are perfectly correct. This figure must be multiplied by another 250,000,000 in reaching out from the nearest star to the limits of our telescopic penetration of space.

These vast numbers need not concern us greatly however, as the relative distances of celestial objects cannot be determined with an accuracy at all comparable with that of the radius of the earth. While the latter has a probable error of one part in 240,000, the distance of the sun is uncertain by one part in 9,000, the nearest star by one part in 150, and at the limit of our telescopes our estimates of distance become very uncertain indeed.

B. THE DISTANCE OF THE SUN

The earth is too small to provide a base line of sufficient length to enable us to extend our measures of distance very far into space. The angle which it subtends soon becomes of the same order as the errors of measurement. It is necessary therefore to find a longer base line. This is provided by the revolution of the earth in its orbit, the measurement of whose radius is second in importance only to that of the earth's radius. This presents the astronomer with one of his most difficult problems. Simple geometric methods are inadequate, as the brightness of the sun obscures the neighboring stars which might serve as reference points for locating its position precisely. Even if the stars were visible, the limb of the sun is not susceptible to refined measurement and there are no permanent features on its surface to provide landmarks. The problem therefore has to be attacked indirectly. Fortunately there are several ways in which this can be done.

Gravitational methods, which depend upon the relative attractions of the sun and a planet for a third body, are capable of yielding reliable results if the ratio of the masses of the sun and planet are known. But complicated mathematical analysis of a long series of observations is necessary. With the perfection of electronic calculators and the accumulation of accurate observational data, this approach to the problem may find greater favor in the future. The finite velocity of light may be used as our yard stick, by observing the time at which some periodically recurring event is seen from different parts of the earth's orbit. Or advantage may be taken of the Doppler displacements of spectrum lines to measure the speed of the earth. The most effective method however is to determine the distance of some nearer object whose distance relative to that of the sun is known. Two applications of such geometric methods

will be briefly outlined.

Venus, our nearest planetary neighbor, passes between us and the sun at rare intervals. These transits occur in pairs eight years apart, the pairs separated by a century or more. The path of Venus across the face of the sun depends upon the observer's position on the earth. Halley, whose fame is perpetuated by the comet which bears his name, suggested that observations of these transits from stations widely separated in latitude might provide an improved value of the solar distance. Elaborate preparations were made to observe the transits of 1761 and 1769 from various parts of the world. But the results were disappointing, as they were vitiated by refraction and irradiation effects which had not been anticipated. For the transits of 1874 and 1882, additional precautions were taken and the aid of photography was enlisted. The values obtained by different observers still proved widely discordant. Newcomb, however, derived a weighted mean for the solar parallax (the angle subtended at the sun by the earth's equatorial radius) of 8".794 which is very close to the accepted value. The next transits of Venus will take place in the years 2004 and 2012, but it is doubtful if they will materially improve the knowledge we will then possess regarding the distance of the sun.

Other bodies in the solar system may also be used for deriving the solar parallax. The planet Mars, at its closest approach to the earth, is only one-third as far away as the sun. The position of its small disk can be measured with considerable accuracy against the background of stars. Sir David Gill spent five months on Ascension Island in 1877 measuring its position with a heliometer, the rotation of the earth providing him with a changing base line from which to note the changing position of the planet. Later some of the brighter asteroids were similarly employed. But the results were contradictory and gave too great a distance for the sun.

In 1898, Witt of Berlin announced the discovery of the minor planet Eros, whose orbit carries it within 13,000,000 miles of the earth at the most favorable oppositions. It is a tiny object only a few miles in diameter and quite stellar in appearance. With improved photographic techniques, it was felt that the close approach in 1931 would provide an excellent opportunity for finding its distance, which at that time would be only one-seventh that of the sun. A well organized plan of campaign was carried out under the auspices of the International Astronomical Union. Observatories all over the world having suitable equipment, including the Leander McCormick Observatory, participated in the enterprise. The monumental task of discussing the accumulated data was undertaken at the Greenwich Observatory by the Astronomer Royal, Sir Harold Spencer Jones. It was ten years before the results were ready for publication. They are based on 2847 plates taken with 30

different telescopes at 24 observatories in 14 countries, as well as on visual observations. For the solar parallax he finds 8″.790 with a probable error of 0″.001. With Hayford's value of the equatorial radius of the earth, this angle corresponds to a distance of 93,004,000 miles for the sun with a probable error of 11,000 miles. This value will no doubt stand for some time as there will be little opportunity to improve it until the year 1975, when Eros once more makes a close approach to the earth. No other object now known seems capable of yielding more accurate data.

C. THE DISTANCES OF THE STARS

The distance of the sun is adopted as the 'astronomical unit' and provides the longer measuring rod necessary for spanning the vast distances between us and the nearest stars. The chief objection encountered by the earliest proponents of the heliocentric theory was the absence of observable backward and forward shifts of the stars as the earth made its annual pilgrimage around the sun. What they did not realize was the minuteness of the apparent displacements owing to the enormous distances of the stars. If they had assumed that, instead of being pinpoints of light on a crystal sphere, the stars rivaled our sun in brilliance, their tremendous distances would have followed logically since apparent brightness varies inversely as the square of the distance. For example, the sun appears to be 10,000,000,000 times as bright as Sirius, the brightest of the so-called 'fixed' stars. This star would therefore be approximately 100,000 times as far away as the sun. Actually Sirius is intrinsically 25 times as bright as the sun, and its distance must be increased another five-fold. Successive generations of astronomers attempted to measure stellar parallax (the angle subtended at the star by one astronomical unit) without success in spite of gradual refinements in their techniques. The failure of the stars to reveal the secret of their distances only served to make them recede farther and farther into the depths of space.

Centuries were to lapse before success was achieved. But in that interval several important discoveries were made in the course of attempts to detect the parallaxes of the stars. Halley in 1718 announced that three of the bright stars had changed their positions in the sky and could no longer be regarded as 'fixed'. It was reasonable to suppose that other stars were moving also and that each star had proper motion of its own. About the same time, Bradley discovered that the stars did describe minute orbits in the sky as the earth made its circuit around the sun. But these orbital motions were not in the right direction to be attributed to the earth's position relative to the sun. In 1728 he published the correct explanation as due to the relative velocity of the earth as compared with the finite speed of light which had been discovered

by Roemer in 1675. This phenomenon is known as aberration and is the same for all stars in the same part of the sky irrespective of their distances. It provides as convincing a proof of the motion of the earth as the parallactic shifts he was seeking. Bradley also discovered the nutation, or nodding, of the earth's pole due to the attraction of the moon on the earth's equatorial bulge.

Another unexpected by-product of the search for the key to unlock the secret of the distances of the stars was made by Sir William Herschel. He attempted to measure stellar parallax by a method suggested two centuries earlier by Galileo. Assuming that a faint star were at a much greater distance than a bright star seen projected close to it on the celestial sphere, he endeavored to detect the difference in their parallaxes by measuring their relative positions. Instead of finding the relative parallax, however, he discovered that the stars were dynamically connected and were revolving about their common center of gravity. Thus he demonstrated that Newton's law of gravitation was truly universal in its application.

Success in measuring the distance of a star was finally achieved in the year 1938 simultaneously by three different observers using three different types of instruments. Bessel at Koenigsberg probably deserves priority for his measurement of the parallax of the star 61 Cygni with the heliometer. Struve at Pulkova determined the distance of the bright star Vega with a filar micrometer attached to what was then a large telescope. At the Cape of Good Hope, Henderson deduced the parallax of the nearest star, Alpha Centauri, from observations with a meridian circle. Of these instruments the heliometer is the only one which, in the hands of skilled observers, has produced results of sufficient accuracy to merit inclusion in our catalogues today.

Spurred by the success of these astronomers, others attacked the problem with renewed vigor. The latter half of the nineteenth century witnessed a great deal of activity in this field and the application of photography to the measurement of the small angles involved. Some conception of the accuracy needed can be gained from the fact that, on plates taken with the McCormick 26-inch refractor which has a focal length of 32 feet, the nearest star would shift its positiion only 1/700 of an inch from its mean place in the course of a year. By the end of the century the distances of about 100 stars were known with a reasonable degree of accuracy.

The modern era had its real beginning with the work of Schlesinger at Yerkes Observatory in the years 1903 to 1905. Ritchie had demonstrated that the 40-inch visual refractor was capable of producing excellent photographs if a yellow filter were used in conjunction with yellow sensitive plates. Schlesinger demonstrated that the large scale of the photographs provided by the focal length of more than 62 feet

could be employed in the accurate determination of stellar parallaxes. He took precautions to avoid the ever-present systematic errors that had vitiated previous photographic work and devised convenient methods of treating the observational data. From Yerkes, Schlesinger was called to the directorship of the Allegheny Observatory where he started systematic observations of all the brighter stars with a new telescope having a lens corrected for the actinic rays to which the ordinary photographic plate is most sensitive. About the same time, Dr. Mitchell was appointed director of the Leander McCormick Observatory and a similar program was undertaken and prosecuted with great vigor. Later Schlesinger moved to Yale and was instrumental in establishing the Southern Station in Johannesburg where I had the privilege of carrying the campaign to the southern stars for a period of twenty years. These three observatories completed their first 1,000 parallaxes in the above order, followed some years later by the Cape Observatory. Each is now nearing the 2,000 mark. Several other observatories have made appreciable contributions, of which one of the most valuable has been the observation of extremely faint stars with the large reflectors of the Mount Wilson Observatory by van Maanen.

The twentieth century has therefore witnessed a significant advance in our knowledge of the spatial distribution of the stars in the immediate neighborhood of the sun. To express their distances without the use of 'astronomical' figures, a new unit is necessary. The one most readily visualized is the 'light-year', the distance that light travels in one year at the rate of 186,000 miles per second. It is equal to 5,880,000,000,000 miles or 63,310 astronomical units. In this unit the distance of the nearest star becomes 4.3 light-years. With our present accuracy we can plumb the depths of space to a distance of only 300 light-years by direct measurement. Only a small fraction of the stars lies within this range. What of those byond?

D. CRITERIA OF DISTANCES

Enough has been learned about the relation between various characteristics of the stars and their distances so that we can use these relations to extend our scale beyond the limits of direct measurement. The first of these criteria is motion. The stars do not move at random but appear to be drifting past us toward a point in the southern sky, with angular velocities proportional to their distances from the sun. The effect is the same as for objects on the landscape viewed from a moving car. This is a consequence of the sun's motion toward the constellation Hercules with a speed of 12 miles per second or 4 astronomical units per year. The reflex of the sun's motion cannot be used to find the distance of an individual star. Its apparent motion will be a combination of its own peculiar motion and that due to the sun. On the assumption that the

peculiar motions of the stars are in random directions, it is possible by statistical methods to find the average distance of any particular class of stars not too remote. This method has the advantage that the effects are cumulative, our base line being proportional to the time that has elapsed between our observations. The Leander McCormick Observatory is now undertaking the determination of the distances of the long period variable stars by comparing plates taken twenty years apart, thus providing a base line of 80 astronomical units.

If all the stars were of the same intrinsic or absolute brightness, their apparent brightness would serve as a useful criterion of distance as previously mentioned. However parallax observations soon revealed that this is not the case. There is a 200,000,000-fold range in the actual luminosities of the stars resulting from their variations in mass, size, and temperature. Fortunately the spectrum reveals the true brightness and this can be compared with the apparent brightness to indicate the distance. This may be in error due to the presence of dark matter in space obscuring the light on its way to the earth. However, the method has proved very useful as it can be extended to any star whose spctrum can be photographed.

The amount of obscuring matter has been used as a measure of distance also, as it makes its presence known by introducing absorption lines into the spectra of the stars beyond, the strength of the lines being proportional to the amount of matter. But the obscuring matter is not uniformly distributed in space so that distances so derived are not trustworthy.

Another clue to distance is to be found in the period-luminosity law. Miss Leavitt, while making a study of the Small Magellanic Cloud at the Harvard College Observatory, discovered that there was a correlation between the mean apparent brightness and the period of light variation of the short period variables known as Cepheids. As the stars were all at the same distance, the same correlation exists between period and absolute brightness. As soon as the zero point of the scale was established, these stars provided a powerful tool for exploring the distant parts of the universe. They are very luminous and can therefore be photographed at great distances.

Cepheid variables were found in globular clusters and helped Shapley locate these outposts of our Milky Way system or Galaxy and define its boundaries. They also enabled Hubble to bridge the gap of intergalactic space and provide the first reliable estimates of the distances of the spiral nebulae. The nearest of these objects is at the tremendous distance of 870,000 light-years. Long exposure photographs with our largest telescopes reveal large numbers of spirals of various sizes down to the limits of the plates. Some 100,000,000 extra-galactic nebulae are within the range of our telescopes. Our best means of

obtaining their relative distances is to assume that on the average they are of the same total integrated brightness or of the same average linear dimensions. In the latter case the distance of any extra-galactic nebula will be inversely proportional to its angular size.

By these means we estimate the range of our present telescopes to be of the order of 1,000,000,000 light-years. What of the space beyond? Does the density of the extra-galactic population continue undiminished indefinitely? Or does the accumulation of mass produce a gravitational field of such magnitude that nothing can remain outside some distant boundary? The new 200-inch Hale telescope on Mt. Palomar will be confronted with these and other problems equally difficult to solve.

Our scale has been extended from a short base line in Egypt 2,200 years ago to the confines of the universe as we know it today. I have deliberately resisted the temptation to stop along the way and view the scenery lest we become too engrossed in some local fauna or flora. No mention has been made of the form and structure of various aggregations of matter, their physical characteristics, possible signs of evolutionary development, space-time relations, or the apparent expansion of the universe indicated by the recession of the nebulae. I have merely presented the skeleton, dry bones for which the astronomer must supply the flesh and blood of physical data in order to provide a complete picture of a living universe.

REFERENCES

For those interested in details there are several good histories of Astronomy or books dealing with science in general during particular periods. For more recent developments see:

HUBBLE, EDWIN 1936—The Realm of the Nebulae. *Yale University Press.*

JONES, SIR HAROLD SPENCER 1941—The Solar Parallax and the Mass of the Moon from Observations of Eros at the Opposition of 1931. *Memoirs of the Royal Astronomical Society,* London 66, Part 2.

MITCHELL, S. A. AND OTHERS 1920—Parallaxes of 260 Stars. *Publications of the Leander McCormick Observatory,* 3, Introduction.

SCHLESINGER, FRANK 1911—Photographic Determinations of Stellar Parallaxes Made with the Yerkes Refractor. *Collected reprints from The Astrophysical Journal,* Chicago.

SHAPLEY, HARLOW 1930—Star Clusters. *Harvard Observatory Monographs,* No. 2.

———————— 1943—Galaxies. *The Harvard Books on Astronomy. The Blakiston Company,* Philadelphia.

Pollen Condition in Some Species and Hybrids of *Rosa* with a Consideration of Associated Phylogenetic Factors

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INTRODUCTION

The genus *Rosa* is large and widely dispersed. Various botanists have recognized from thirty (Bentham and Hooker) to many thousands (Gandoger) of species in the genus.

Its probable one to two hundred species are chiefly scattered throughout the frigid, and especially the temperate and sub-tropical regions of the northern hemisphere (Rehder, 1940). In the United States, for instance, every state has its wild roses (Little, 1942). A few species occur in the tropics in Abyssinia, Arabia, and India. Considerable variability is exhibited from species to species, and often within the same species or species complex. The genus is a difficult one in many ways. Numerous problems, especially of speciation and relationship, still exist despite the extended researches of Michaux, Nuttall, Lindley, Christ, Crepin, Baker, Hurst, Erlanson and others.

Several years ago the Texas Agricultural Experiment Station assembled all available species, hybrids, and botanical varieties of *Rosa* at its Substation Number 2, near Tyler. Designed chiefly for use in an extensive breeding program to develop improved rose rootstocks, the collection also afforded excellent material for various genetic and cytological studies. One of the studies made involved the analysis of pollen collected over a period of five years from the several species and hybrids. Brief progress reports of this have appeared (Ratsek, Flory, and Yarnell, 1939; Flory, 1940 and 1941). This study was designed to determine (1) the relative amounts of normal appearing pollen encountered in the various species and groups of *Rosa,* and (2) the light which such information might shed on the phylogeny of the genus. Final data and results of the pollen study are presented in this paper. All available data from earlier studies of rose pollen condition are included in summary form.

PREVIOUS STUDIES OF ROSE POLLEN

Focke (1881) listed a number of *Rosa* species with mainly well formed pollen, and pointed out that in the Caninae section much malformed pollen occurred. According to Crepin (1889), Christ in 1884 referred to atrophy of pollen grains in rose hybrids but did not go into any detail.

Crepin (1889), Cole (1917), and Erlanson (1929, 1931) have reported studies of the pollen condition encountered in some 70 species of roses. These reports are summarized in Table 1. Chromosome counts were given for the plants studied by Erlanson, but not for those used in the earlier works. In some species Erlanson (1931) studied the pollen of a number of different plants and found that some groups (especially *R. blanda, R. Woodsii,* and the tetraploids) showed a considerable range of variation as between individuals, while such variation

was lacking in other cases.

Harrison and Blackburn (1927) have given the per cents of good pollen found in the several species groups of the section Caninae. Since only a few of these are duplicated in the present work the counts are not presented in Table 1. The rose species studied by Harrison and Blackburn with the "yield . . . . percentages of good pollen" follow in the order listed by the original authors:

0-10 Per Cent

subscristata, Reuteri, subcanina, fugax, inconspicua, biserrata, echinocarpa, Borrerih, coerulea, pseudorubiginosa, tomentosa.

10-30 Per Cent

frutetorum, coriifolia, venosa, lutetiana, hemitricha, aciculata, comosa, sylvestris, pseudocuspidata, foetida.

30-50 Per Cent

flexibilis, rubrifolia, submollis.

50-70 Per Cent

fallens, omissa.

70-90 Per Cent

senticosa, mollis.

TABLE I. Amounts of normal pollen in *Rosa* species, as reported by other authors.

Rosa species	2n*	Author reporting	No. of plants	Av. % of normal pollen	Range in % of normal pollen
acicularis	56	Erlanson[1]		96.4	
acicularis	42	Erlanson[2]	23	92.5	82.5-100
acicularis		Cole		72.5	(50-90)
acicularis Lindl. var.		Crepin[3]		pure	
acicularis Lindl. var. lacorum	42	Erlanson[2]		92.7	91.6-94
acicularis var. *lacorum*	42	Erlanson[1]		91.6	
alba		Cole		poor	(0-50)
aldersonii	28	Erlanson[1]		78.	
alpina L.		Crepin		pure	
arkansana Porter	28	Erlanson[3]		20.0	19.5-20
arkansana Porter	28	Erlanson[2]		80.0	76.-84
arkansana, R. suffulta	28	Erlanson[2]	28	73.9	51.0-92.0
arvensis		Cole		25.0	(0-50)
arvensis Huds.		Crepin		pure	
Beggeriana Schrenk		Crepin		pure	
blanda	14	Erlanson[1]		90.0	
blanda	14	Erlanson[1]		48.0	
blanda	14	Erlanson[2]	28	79.1	42.7-98.0
blanda		Cole		80.0	50-90
blanda Ait		Crepin		pure	

Rosa species	2n*	Author reporting	No. of plants	Av. % of normal pollen	Range in % of normal pollen
blanda var. *glandulosa*	14	Erlanson[1]		82.4	
blanda var. *glandulosa*	14	Erlanson[1]		75.0	
blanda var. *hermanni*	14	Erlanson[1]		94.0	
blanda var. *hispida*	14	Erlanson[1]		95.7	
blanda var. *hispida*	14	Erlanson[2]		76.0	
bushii	28	Erlanson[1]		74.0	72.-80.
butleri	42	Erlanson[1]		100.0	(8.3 angular grains)
californica	28	Erlanson[1]		74.0	
californica	28	Erlanson[2]	4	76.7	74.0-81.7
californica Cham. *et* Schiecht		Crepin		sometimes pure sometimes ⅓ pure pollen	
canina biserrata		Cole		10.0	0-50
canina L.		Crepin		⅓-⅔ good	
carolina		Erlanson[1]		74.6	
carolina		Erlanson[1]		90.5	
cinnamomea		Cole		100.0	90.-100.
clinophylla Thory		Crepin		pure	
coriifolia		Cole		poor	0-50
damascena		Cole		40.0	0-50
davurica		Cole		70.75	50-90
Engelmanni	42	Erlanson[1]		89.2	
Engelmanni S. Wats	42	Erlanson[2]		96.1	94.2-98.
Fendleri		Erlanson[3] (highly sterile plant)		22.0	
Fendleri	14	Erlanson[1]		74.4	
Fendleri Crepin	14	Erlanson[3]		43.6	37.3-50
ferruginea		Cole		poor	0-50
ferruginea Vill.		Crepin		½-⅔ good	
foliolosa	14	Erlanson[2]		48.8	
foliolosa	14	Erlanson[3]		89.0	
gallica		Cole		25.0	0-50
gallica L.		Crepin		pure	
graveolens Gren. Var.		Crepin		1/10 of total good	

Rosa species	2n*	Author reporting	No. of plants	Av. % of normal pollen	Range in % of normal pollen
gymnocarpa	14	Erlanson[3]		91.0	50-90
gymnocarpa		Cole		80.0	50-90
Harrisoni (garden hybrid)		Cole		60.0	50-90
hemispherica		Cole		poor	
indica Lindl.		Crepin		not abundant	
Jundzillii Bess		Crepin		¼ good	
kamchatica		Cole		40-50	0-50
kamchatica Vent.		Crepin		pure	
kelleri		Cole		100	90-100
lucida Ehrh.		Crepin		pure	
macrophylla		Cole		0+	0-50
Manetti (garden hybrid)		Cole		60.0	50-90
michiganensis	14	Erlanson[1]		96.4	
micrantha Sm.		Crepin		½ good	
mollis		Cole		40.0	0-50
moschata Herrm. var.		Crepin		nearly pure	
muriculata Greene	42	Erlanson[3]		88.8	86.0-93
Moyesii		Cole		100.0	90-100
multiflora		Cole		80.0	50-90
multiflora		Crepin		pure	
nutkana Presl.		Crepin		pure	
oxydon		Cole		25.0	0-50
palustris	14	Erlanson[1]		90.5	
palustris	14	Erlanson[1]		95.2	
palustris	14	Erlanson[1]		90.0	
palustris	14	Erlanson[3]	12	92.0	78.25-99.8
pimpinellifolia L.		Crepin		pure	
pisocarpa	14	Erlanson[3]		91.5	
pisocarpa	14	Erlanson[3]		87.7	
pisocarpa		Crepin		pure	
pendulina		Cole		100.0	90-100
platycantha Schrenk		Crepin		pure	
pratincola		Cole		75.0	50-90
relicta Erlanson	28	Erlanson[3]		29.0	12.0-44
relicta	28	Erlanson[1]		33.5	23-44
rubiginosa		Cole		0+	0-50
rubiginosa L.		Crepin		½-⅔ good	
rudiuscula	28	Erlanson[1]		74.2	
rugosa		Cole		100	90-100

Rosa species	2n*	Author reporting	No. of plants	Av. % of normal pollen	Range in % of normal pollen
rugosa	14	Erlanson[2]		77.2	
rugosa alba		Cole		60.0	50-90
rugosa alba		Cole		60.0	50-90
rugosa arnoldiana		Cole		5.0	0-50
rugosa plena		Cole		10.	0-50
rugosa Thumb.		Crepin		abundant pure	
salicetorum	14	Erlanson[1]		62.0	
schuetteana	14	Erlanson[1]		91.7	
sempervirens		Crepin		abundant mostly good	
Seraphinii		Cole		90.0	50-90
sericea Lindl.		Crepin		pure	
setigera Mich.		Crepin		well developed	(many don't become spherical under action of water)
setigera		Cole		no good	0-50
setipada		Cole		0+	0-50
Spaldingii	42	Erlanson[1]		91.4	
Spaldingii	42	Erlanson[1]		92.0	
spinosissima		Cole		90.0	50-90
spinosissima		Cole		60.0	50-90
spinosissima (garden variety)		Cole		60.0	50-90
spinosissima hispida		Cole		90.0	50-90
spinosissima paniculata		Cole		90.0	50-90
subblanda	14	Erlanson[2]		91.7	91.4-92
suffulta	28	Erlanson[1]		84.5	
suffulta	28	Erlanson[1]		71.0	
suffulta Greene	28	Erlanson[2]		83.4	82.3-84.5
suffulta Greene	28	Erlanson[2]		52.9	51.0-55
suffulta Greene		Erlanson[2]		74.0	71.0-76.9
tomentosa Sm.		Crepin		⅓-⅔ good	
ultramontana		Erlanson[1]		95.3	
ultramontana		Erlanson[2]		95.0	
underwoodii		Erlanson[1]		91.7	
villosa L.		Crepin		⅓-⅔ good	
virginiana	28	Erlanson[1]		75.6	
virginiana	28	Erlanson[1]		90.0	

Rosa species	2n*	Author reporting	No. of plants	Av. % of normal pollen	Range in % of normal pollen
virginiana Alba		Cole		75.0	50-90
virginiana Alba		Cole		75.0	50-90
virginiana Mill	28	Erlanson[2]		89.6	89.3-90
virginiana Mill	28	Erlanson[2]		92.5	92.0-93
virginiana; carolina	28	Erlanson	28	80.7	48.4-93.0
virginiana plena		Cole		10.0	0-50
wichuraiana		Cole		numerous shriveled grains	50-90
wichuraiana		Crepin		¼ atrophied grains sometimes pure	
Woodsii	14	Erlanson[1]		91.0	
Woodsii	14	Erlanson[2]	28	76.3	37.3-96.0
Woodsii Lindl.	14	Erlanson[2]		71.5	71.0-72.0
Undetermined species	21	Erlanson[2]	4	6.0	
Undetermined species	21	Erlanson[1]		0.0	
Undetermined species	21	Erlanson[1]		3.0	
Undetermined species	21	Erlanson[1]		7.3	

[1]1929 paper
[2]1931 paper
[3]Crepin used "pure pollen" in the sense that most of it was well developed, and atrophied grains were rare.
*Chromosome number

A comparison of the combined material in Table 1, and in the list preceding it, with the species observed in the present work and listed in Table 2 reveals some overlaps. Approximately 112 species and varieties previously studied by other workers are listed. Slightly more than a third of these, or of similarly named material, have been examined in securing present data and are included with the species and varieties arranged in Table 2. Some variations exist in the results of the different studies. There is, however, a surprising agreement in per cents of normal pollen observed. This is especially true when the plant-to-plant variation within some species (Erlanson, *loc. cit.*) is considered, and along with this the fact that different chromosome numbers probably existed in some of the comparative cases involving plants on which counts were not made by earlier authors. Comparative data agree favor-

ably in most cases where the several investigators were working with plants of known similar chromosome number.

MATERIALS AND METHODS

The species and varieties used were obtained from the following sources: Bobbink and Atkins, the Arnold Arboretum, Cornell University, and the United States Department of Agriculture. Two or three forms of *Rosa multiflora* were obtained from Texas nurseries. Two *multiflora-blanda* hybrids were secured from the late Professor T. J. Maney of Iowa State College. The species were checked with descriptions in Willmott's "The Genus Rosa" (1914) and in Rehder's Manual (1940). Rehder's arrangement of species with respect to generic sections is followed.

The hybrids (other than those mentioned in the preceding paragraph) were produced in the breeding program (*loc. cit.*), and their derivation has been discussed elsewhere (Ratsek, Yarnell, and Flory, 1939; Ratsek, Flory, and Yarnell, 1940).

Names of species and varietal material are listed in alphabetical order in Table 2. As this list shows, the study included forms which might be included in the following approximate categories: 95 species of *Rosa,* six botanical varieties of additional species, 29 botanical varieties (belonging to certain of the first 95 species), five cytological variants, 14 horticultural varieties, three horticultural forms, and two hybrids.

Twenty-six unnamed lots are listed in Table 3. Some hybrids may be included here, but these are probably chiefly specific material with some being duplicates, apparently, of the named species used. Pollen studies were made of these as indicated in Table 3. While no analysis has been made of the data for taxonomic reasons, these are included here in order that this paper may present all available results from studies on rose pollen.

The 34 interspecific crosses from the breeding program, resulting in plants which flowered and produced pollen during the course of this study, are listed in Table 7. Herbarium specimens of the plants involved here have been deposited in the Tracy Herbarium of Texas A. & M. College, along with taxonomic vouchers for many of the species studied.

Pollen was collected from flowers about to open by pulling the anthers out with forceps, allowing them to dehisce on paper, and transferring the pollen to labelled vials. Pollen was secured from several plants where possible, but often only one; in several instances two or three plants were available but these sometimes had the same vegetative source. The present study, therefore, was not designed so as to furnish much information concerning variation in the amounts of aborted pollen found from plant to plant within the same species.

In making the pollen studies mounts in acetic acid containing a small amount of iodine were prepared. At least 500 grains were counted in most samples. The sample size was established after considering the statistical determination of an adequate sample for plum pollen (Flory and Tomes, 1943), the variation found in rose pollen from flower to flower, and when possible, from plant to plant, and other factors which indicated this size of sample to give as accurate information as permitted by other variables in the experimental set-up. Plump, regular appearing grains that were filled with cytoplasm were counted as normal in appearance, others were counted as aborted. Mounts were manipulatd by a mechanical stage so as to avoid duplicate counts and insure random sampling. Mechanical hand tallies were used in taking the counts, all of which were made at a magnification of 200 diameters.

No germination studies were made with *Rosa* pollen. It has been found in *Prunus*, a related genus, that when all varieties studied in a single year were considered together, a significant correlation existed between percentages of normal appearing pollen and actual germination in each year, although the proportion of germinating pollen was always lower than that of normal appearing pollen (Flory and Tomes, 1943). The same condition might be expected to exist in *Rosa*, and the expectation seems verified from results of the breeding program (Ratsek, Yarnell, and Flory; Ratsek, Flory, and Yarnell, *loc. cit.*).

The pollen examinations were based on pollen collected in the springs of the years from 1939 to 1943 inclusive. Most examinations were made soon after the pollen was collected, although some samples were carried over for study in later periods as time permitted. Samples from some forms were secured in only a single year; from the majority of species and varieties pollen collections and studies were made for each of two, three, four or — in two cases — five years (Table 2).

CHROMOSOME NUMBERS

Tackholm, Hurst, Harrison, Erlanson, and others have reported chromosome counts for most *Rosa* species. A partial list of these combined counts is included in Darlington and Janaki-Ammal's "Chromosome Atlas of Cultivated Plants" (1945). These lists show that polyploidy within the same species is a common phenomenon in *Rosa*.

Except in Table 1, the chromosome numbers listed in this paper for the various *Rosa* species, varieties, and hybrids have usually been determined for the actual plants worked with and from which pollen has been collected. These determinations were made by the writer and, more especially by the writer's associates (Doctors S. H. Yarnell and H. T. Blackhurst) during the period that the field study was under way (Flory 1940; Ratsek, Flory, and Yarnell 1939; Yarnell, 1940; Yarnell and Blackhurst, 1941.) These somatic counts were made from leaf smears according to Baldwin's (1939) method. Any uncertainty as to

counts is indicated in Table 2. If the uncertainty pertained to the number of chromosomes observed this is indicated by a question mark. Parentheses have been used in a few cases around numbers established by others, and not verified by our plants, where the material seemed of unquestioned identity.

Since meiosis plays perhaps an even more important part in the resulting pollen condition of roses than is true in most plants, some explanation should be given here of what will need to be referred to later. Tackholm (1920, 1922) and Blackburn and Harrison (1921) almost simultaneously worked out the peculiar cytological details of *Rosa*. A polyploid series based on the chromosome number of seven was reported. Pentaploids, and to some extent triploids, were well represented. The pentaploids, which are prevalent in the Caninae are of irregular or "unbalanced" meiotic behaviour: 7 bivalents and 21 univalents occur; at anaphase I the bivalents separate normally while the univalents later divide with sister halves going to opposite poles; at anaphase II the 7 chromosomes from the original bivalents divide and sister halves go to each pole, while the univalents—having previously divided—are scattered at random around and between the poles. The most obvious result is the formation of many, often small, supernumerary nuclei; a less obvious result is probably the formation of microspores with extra chromosomes. The microspores receiving exactly 7 chromatids from the original bivalents are assumed to be the functional ones, the others becoming abortive. Perhaps more astonishing yet, the tetraploids and hexaploids of the Caninae were found to be of two types: (1) the expected type with regular or "balanced" meiosis; and (2) a type with 7 bivalents and 14, or 28 (if hexaploid) univalents which behave as in the pentaploids, with 7-chromosome functional pollen and many aborted microspores eventuating.

In the embryo-sac mother cells of these unbalanced forms, all the univalents go to one end of the cell where they are joined by a reduced 7 of the bivalents. These together eventually form an embryo-sac containing an egg-cell with 21, 28, or 35 chromosomes depending on whether it is in a tetraploid, pentaploid or hexaploid form. This, following fertilization with a 7-chromosome microspore, gives rise to a new embryo and individual with the chromosome number of the original parent.

POLLEN CONDITION IN SPECIES AND VARIETIES

The per cents of normal appearing pollen observed in the several species and varieties of *Rosa* available for this study are presented in Table 2. The columns of this table contain from left to right: the accessioned names of the several roses, the somatic chromosome numbers of the plants studied, the geographical area where the roses are native, the number of years that pollen observations were made, the average

percents of normal appearing pollen observed, and the range in such per cents where counts were made in more than one year, or where counts were made from more than one plant in a single year. The figures under "range" represent year to year variation in occurrences of normal pollen, but this is also affected in some cases by plant to plant variation where different plants, or different numbers of plants, were used in different years.

TABLE 2. Per cents of apparently normal pollen in the several *Rosa* species and varieties studied.

Species or variety of *Rosa*[1]	2n[2]	Native[3]	No. yrs. studied	% normal pollen	
				Average	Range
abyssinica (moschata)	14	Abyssinia	1	90.1	
acanthoclada	14		2	74.7	71.0-78.4
acicularis	28	Alaska to Wyo. Mich. to N. Y.	1	78.8	76.3-81.4
acicularis Engelmanii	14	N. W. U. S.	2	92.1	84.9-97.1
acicularis Engelmanii	42	N. W. U. S.	2	33.7	30.4-37.0
acicularis nipponensis	14	E. Asia	2	75.3	73.1-76.0
adenosepala (Woodsii)	14	New Mexico	1	75.3	
alba	28 (42)	Cult. S.E. Eur.	1	22.9	
Alberti	35	Turkestan	2	12.0	11.3-12.7
alpina (pendulina L.)	28 (?)	Mts., S.&C. Eur.	1	81.5	78.5-84.5
amblyotis	14	N.E. Asia on Bering Sea	2	92.9	90.2-94.8
Andreae	14	E. Asia	3	41.6	30.5-50.0
arvensis	14	Europe	2	43.8	39.9-47.8
arvensis sylvestris	14	Europe	2	95.4	87.4-98.0
baltica	(35)	Europe	2	15.9	6.0-25.8
banksiopsis	35	W. China	3	41.5	24.8-49.6
Beggeriana	14	Persia	2	92.3	81.0-99.0
belgradensis	35	Serbia, S. Eur.	2	13.7	7.7-19.5
blanda (A)	28	America	3	38.7	28.0-47.4
blanda (B and C)	14	America	3	91.6	84.5-95.3
bracteata	14	China	1	97.1	
canina	35	Europe	3	9.8	6.0-14.3
canina montivega	35		2	16.7	10.0-23.5
carolina	(14 or) 28	United States	2	94.8	92.0-97.6
caudata	28	W. China	2	62.9	50.6-73.2
centifolia	28	E. Cauc.	2	68.3	61.7-71.5
centifolia	35		1	24.8	
centifolia muscosa	28	E. Cauc.	2	17.9	12.4-23.5
centifolia salet	28	E. Cauc.	1	33.1	

Species or variety of *Rosa*	2n[a]	Native[a]	No. yrs. studied	Average % norm	
cinnamomea	56	Eur. N.&W. Asia	4	93.3	81.0-98.7
coriifolia	35	Eur. & W. Asia	1	28.7	21.7-36.5
coriifolia cinera	14	Eur. & W. Asia	3	77.4	62.0-83.2
coriifolia froebeli	35	Eur. & W. Asia	2	40.4	34.7-46.0
cymosa	35	China	3	16.5	8
damascena	28 or 35	Asia Minor	3	31.2	
damascena trigintipetala	28	Asia Minor	1	18.2	
damascena versicolor	28	Asia Minor	2	45.8	
Desiglisei (near *canina*)	42	Europe	2	35.3	
dumalis (near *canina*)	35	Eur., W. Asia	1	9.3	
dumetorum Thuill	35	Eur., W. Asia, Af.	2	23.8	
Fendleri Crep.	14	N. America	3	95.7	
ferox	35	E. Eur. & W. Asia	3	16.5	
foetida	28	W. Asia	1	20.0	
foetida bicolor	28	W. Asia	1	7.0	
foetida persiana	28	W. Asia	2	12.4	
Fujisanensis (var. of *Luciae*)	14	E. Asia	1	68.7	
gallica	28	S. Eur. & W. Asia	2	56.2	
gallica conditorum	28	S. Eur. & W. Asia	3	41.3	
gallica splendens	28	S. Eur. & W. Asia	2	74.2	
Gayiana (*Gayi*?)	35	Europe	2	18.6	
gigantea (var. of *odorata*)	14	S.W. China	1	62.0	
Giraldii Crep.	14	C. China	1	67.6	
grandiflora Lindl.	14	Eur. & W. Asia	2	74.6	
gymnocarpa	14	W. N. America	2	90.3	8
Harrison's Yellow (*foetida* x *spinossissima*)	28	W. Asia, & Eur.	2	27.3	2
Helenae	14	C. China	1	5.0	
heliophila Greene	28	W. Asia	1	3.8	
hibernica glabra	42	Eur. & W. Asia	3	4.6	
hibernica gravesii	42	Eur. & W. Asia	2	10.5	
Hugonis	14	C. China	2	84.9	7
humilis Marsh	28	E. N. America	1	67.1	
humilis	14	E. N. America	2	48.4	4
humilis (*nitida*?)	28	E. N. America	3	92.2	88.
inodora	35	Europe	2	4.4	3.0-
I. x L. (*multiflora* type)	21	E. Asia (?)	1	27.8	
Jackii (var. of *Maximowicziana*)	14	Eur., W. Asia	2	93.3	90.
Jundzillii	42	Eur., W. Asia	2	87.9	85.

variety	2n[a]	Native[a]	No. yrs. studied	Average	Range
				% normal pollen	
curdistana	42		2	18.6	17.8-19.4
laxa	28	Asia (Turkestan)	3	85.7	65.0-98.0
laxa	35		2	12.8	11.0-14.6
tierana	14	S. & C. Eur.	2	22.4	12.1-32.6
lin x chinensis)	14	E. China	1	91.2	
	28	E. U.S.	3	94.8	93.7-95.7
	35	Europe (?)	2	12.8	6.9-18.8
Pursh. (?)	28	E. U.S.	2	89.9	87.8-91.9
	42	W. N. America	4	83.6	77.0-90.6
	28	France	2	89.8	89.4-90.2
IV.	28	China, S. Eur., W. Asia	2	60.4	59.4-61.3
:ziana	14	E. Asia	1	88.8	
eziana pilosa	14	E. Asia	2	77.2	73.0-81.5
sis	14	Michigan	1	98.2	
x *palustris*)	28	Eur. Med.	2	43.9	35.4-48.8
. E. M."			1	17.1	
	42	Eur., W. Asia	2	20.0	13.7-26.4
	14	S. Eur., N. Af.	1	98.6	
a	35	Europe	3	11.2	4.0-21.6
anina x *issima*?)	35		5	9.1	5.0-12.3
	42	S. Eur., W. Asia, Africa	2	11.2	6.0-16.4
	14		1	42.0	
d floribunda	28		2	92.4	90.7-94.2
a grandiflora	28		2	38.4	34.8-42.0
a nivea	28		3	36.9	29.8-46.0
flora	14	E. Asia	3	92.3	83.0-99.0
ra cathayensis		China	1	65.0	
a chenault	14		2	84.0	75.0-93.0
ra grandiflora	14		3	92.5	89.6-97.2
a Iowa			2	47.8	42.7-52.8
a Jones			1	42.3	
ra platyphylla	14		2	11.5	9.0-14.0
flora Shafter	14		2	84.6	75.0-94.2
a upright	14		2	87.4	81.0-93.8
ora Welch	14		2	85.8	75.2-93.5
ora-blanda A	21(?)		1	69.1	
ora-blanda B	14(?)		1	34.6	

Species or variety of *Rosa*	2n[2]	Native[3]	No. yrs. studied	Average	Range
				% normal pollen	
mundi (*R. gallica versicolor* according to B. & A.)	35		5	8.4	4.5-13.5
nitida	28	E. N. America	3	94.8	91.1-97.3
nutkana	42	W. N. America	3	97.7	95.0-99.0
ochroleuca Swartz	28	Eur., W. Asia	1	55.9	
odorata	14	China	3	43.2	40.0-49.0
omeiensis pteracantha	14	W. China	2	91.1	87.3-95.0
oreophila	35	Colorado	2	85.4	75.9-94.9
oxyodon Boiss	28	Cauc.	2	95.6	95.0-96.2
palustris	28	E. N. Am.	3	87.0	81.0-90.2
pendulina	28	S. &. C. Eur.	3	85.4	81.5-89.7
pisocarpa	14	W. N. Am.	2	95.2	95.0-95.4
Pouzini	42(?)	W. & S. Eur.	1	12.3	
pratincola Greene	28	Cent. N. Am.	3	93.9	91.1-95.8
primula ("*R. Ecae*," B. & A.; near *xanthina*; pollen suggests 2n=28)	28	Turkestan	1	30.0	
"Purple East"			1	7.0	
"Radiance"			1	39.0	
"Ragged Robin"	21		2	10.3	8.0-12.6
Roulettii (*multiflora* type)		China	2	49.6	46.2-53.0
Roxburghii hirsuta	14	Europe, Asia	1	92.2	
rubiginosa	35	Europe	2	28.2	22.5-38.8
rugosa	14	E. Asia	2	86.0	77.0-95.0
rugosa alba	14		2	95.5	94.0-97.0
rugosa alba (fl. wh.)			1	96.0	
rugosa alba (fl. pink)			1	81.1	
rugosa Chamissoniana	14		2	97.6	97.1-98.0
rugosa repens			1	7.4	2.9-11.9
sempervirens	14	E. Eur., N. Af.	1	39.4	34.7-45.0
Seraphinii Viv.	42	S. Eur., Med.	2	68.8	65.1-71.9
sericea (near *omiensis*)	14	Himal.	1	1.5	
setigera	14	E. & C. N. Am.	1	95.4	
"Silver Moon"	21		4	14.0	8.0-18.6
Soulieana	14	E. China	1	22.4	
Soulieana	(?)		1	90.4	
spinosissima	28	Eu., W. Asia	2	86.0	74.2-96.4
spinosissima altaica	28		2	92.8	90.6-95.1
spinosissima hispida	28	Siberia	2	76.0	66.3-83.8
suberecta	28	Anglia (Cent. Canada)	2	22.9	

Species or variety of *Rosa*[1]	2n[2]	Native[3]	No. yrs. studied	Average	Range
				% normal pollen	
suffulta	28	Cent. N. Am.	1	86.0	
suffulta alba	28	Cent. N. Am.	2	90.2	87.4-92.5
"Talisman"			1	44.0	
"Thornless Rambler"			1	46.0	
urens (could this be *uriensis tomentosa*?)	28		1	89.6	
vierres ch.	14		2	89.2	80.2-98.2
villosa recondita	28	Eur., W. Asia	4	62.4	49.8-75.0
villosa recondita	14	E. N. Am.	1	97.8	
virginiana	28	E. N. Am.	2	86.6	84.8-88.4
Waitziana macrantha (*gallica* x *canina*)	35	Europe	2	34.0	24.8-35.4
Watsoniana	14	E. Asia	4	47.7	34.8-60.1
Webbiana	14	W. & C. Asia	2	59.2	58.8-59.5
Wilmottiae Hemsl.	14	W. China	2	91.0	89.7-92.2
Woodsii (?)	14	W. N. America	1	63.0	
xanthina	14	E. Asia	3	67.0	57.0-73.9
xanthina allard	28		4	27.5	15.0-35.0
Unknown climber			1	21.9	

[1] The name given first is that under which the material was received and carried, at first at least, in the rose cultures. Apparent hybridity, synonymy, etc. are indicated in parenthesis in some cases. Botanical authors, listed in a few cases to indicate the materials carried under indicated names, have been abbreviated as follows: B.&A.—Bobbink and Atkins; Boiss.—E. Boissier; Crep.—F. Crepin; Criv.—G.G.B. Crivelli; Ehrh.—F. Ehrhart; Greene—E.L.G. Greene; Lindl.—John Lindley; Marsh.—H. Marshall; Pursh.—F. T. Pursch; Swartz—Olof Swartz; Viv.—D. Viviani.

[2] Chromosome number

[3] Abbreviations used: Af.—Africa; Am.—America; C.—central; Cauc.—Caucasus; Cult.—cultivated; E.—east; Eur.—Europe; Him.—Himalaya; Med.—Mediterranean; Mich.—Michigan; mts.—mountains; N.—north; N.Y.—New York; S.—south; U.S.—United States; W.—west.

TABLE 3. Per cents of apparently normal pollen in *Rosa* "species" secured through the U. S. Plant Introduction Division.

[1]Location	[2]2n	[3]T.S. No.	[3]P.I. No.	1941	1942	1943	Average
R 14-4	35	28346	109153	27.6		47.3	37.5
14-6	35	28345	109364	14.2		10.1	12.1
14-9	14	28343	122547			87.9	87.9
14-10	14	28343	122547	73.0		87.8	80.4
14-11	35	28831	122548			36.0	36.0
14-17	35	28339	122560	22.5	48.9		35.7
14-18	35	28339	122560		30.1	29.3	29.7
14-19	35	28338	122561			5.0	5.0
14-20	35	28338	122561		9.4	4.3	6.9

[1]Location	[4]2n	[2]T.S. No.	[3]P.I. No.	1941	1942	1943	Average
14-23	28	28336	122567			14.9	14.9
14-24	28	28336	122567		24.3	24.9	24.6
15-2	35	28335	122572		24.2	15.9	20.0
15-3	35	28334	?			21.5	21.5
15-4	35	28334	?		12.5	25.3	18.9
15-7	14	?	122947		95.3		95.3
15-9	42	28332	126281			17.6	17.6
15-10	42	28332	126281			39.7	39.7
15-11	42	28331	126372		20.4	16.8	18.6
15-12	42	28331	126372			33.4	33.4
15-13	35	?	?		24.4	15.0	19.7
15-14	35	28329	126374			17.3	17.3
15-15	35	28330	127744		22.2	20.9	21.5
15-17	35	28328	127751		28.4	21.4	24.9
15-18	35	28328	127751		25.9	48.1	37.0
15-19	35	28327	127754		22.4	25.3	23.9
15-21	14	28325	130335		98.2	69.4	83.8

[1] Row and plant number, Texas Agricultural Experiment Station, Horticultural Farm, College Station, Texas.
[2] Texas Station Accession number.
[3] U.S. Plant Introduction number
[4] Chromosome number

It will be noted from Table 2 that the average per cents of normal appearing pollen varies from 1.5 for our *Rosa sericea* to 98.6 for *R. montana*, with that of the other forms studied falling between these extremes of fertility. There is a preponderance of forms falling within the upper ranges: 58 (out of 156, or over 37 per cent) of the groups studied had 80 per cent, or more, of their pollen of normal appearance.

Pollen containing a small proportion of functional grains may occasionally result in sets and seeds when used on certain seed parents. It is obvious, however, that pollen parents producing relatively high per cents of normal pollen should usually be more effective, in compatible crosses, than pollen parents which produce many aborted and empty grains. The data presented in Tables 1 and 2 and at certain points in the text give general indications concerning such effectiveness for a comparatively large number of *Rosa* species and varieties.

SEASONAL VARIATION IN POLLEN

The season to season variation in the proportion of normal appearing pollen produced was relatively slight for most species and forms. As is indicated in Table 2, 73 forms were studied in each of two years, 26 in

each of three years, six in four different years, and in two species, *R. morica* and *R. mundi*, pollen was examined in each of the five years of the study. This gave ample opportunity to observe the variation in proportions of pollen abortion from one year to another. When the seasonal range in comparable plants is considered (whether over a 2, 3, 4 or 5 year span), the average variation was under 10 points. The greatest range was just over 30 points, and in only some half dozen cases was it 20 points or more. In considerably over half the forms examined, the year to year pollen variation was well under ten points.

As mentioned earlier, the present data were not taken in such a way as to give much information concerning plant to plant variation within a species. In several cases, as was found with *R. caudata* in 1940, with *R. cymosa* and *R. damascena trigintipetala* in 1943, as well as in other instances, there was evidence that such plant to plant differences in the occurrence of aborted pollen do exist. Erlanson, as previously cited, found marked plant to plant variation in some *Rosa* species, believing this to be due to a segregation of sterility factors. The season to season variation for a given species, as suggested in the "range" column of Table 2, doubtless shows the effect of such plant to plant differences in several cases. Also, the apparent season to season variation is probably magnified in some places by sampling techniques, although it is felt that errors from this source were reduced to a minimum. When all these points are taken into consideration it appears that season to season variation in the proportion of normal appearing pollen, particularly with reference to the same individual of a given species, is usually of little significance. Such variation as occurs appears to be greater in some species and varieties than in others.

Heat (Stow, 1926-1927, with potatoes; Sakamura and Stow, 1926, with *Gages;* Heilborn, 1928, with apples, etc.) and cold (Blakeslee and Cartledge, 1927 with *Datura*; etc.), as well as irradiation (Stadler, 1931, with corn; etc.), and other agencies, are known to increase pollen abortion. Such factors, some possibly present in the normal fluctuations of spring temperatures, do not appear to have played a significant part in arriving at the results secured during the five year period covering these experiments. In a given year about as many species have a higher than average per cent of normal appearing pollen as have a lower per cent.

The present conclusions with respect to seasonal variation in rose pollen, are in general agreement with the work reported by Erlanson (1931). Such discrepancies as occur in the two studies might be expected because of differences: in the species studied, in seasonal environments, and in the length of the periods (two years as compared with two to five years) over which the pollen examinations took place.

VARIATIONS ENCOUNTERED IN PER CENTS OF NORMAL APPEARING POLLEN

In Chromosomal Variants of the Same Species.—In several cases marked differences occurred in the per cents of aborted pollen found on different plants carried, and apparently correctly so in most cases, as one and the same species. In some of the extreme cases of this, chromosome number differences within the polyploid series were found to be present. The diploid form of *R. acicularis Engelmanii* had an average of 92.1 per cent normal appearing pollen, but in the better known hexaploid of this, only 33.7 per cent of the pollen appeared normal. In *R. moschata* the diploid averaged 42 per cent, the hexaploid only 11.2 per cent, and the tetraploid variety *floribunda* 92.4 per cent, while two other tetraploid varieties approximated the diploid form in average per cent of pollen of normal appearance. The tetraploid identified as *R. villosa recondita,* and which showed relatively great year to year variation in pollen abortion, averaged 62.4 per cent normal appearing pollen, while the corresponding figure for the diploid form, in the single year it was observed, was 97.8. Similar variations in pollen appearance were encountered in the varying-chromosomed forms of *R. blanda* (diploid or 2x-91.6 per cent of pollen normal; 4x-38.7%), *R. humilis* (2x-48.4%; 4x-67.1%), *R. laxa* (4x-85.7%; 5x-12.8%); *R. Beggeriana* (2x-92.3%; 3x-0%) and *R. centifolia* (4x-68.3%; 5x-24.8%). In the triploid of *R. Beggeriana,* and perhaps in the pentaploid species studied, there may be reason to suspect hybridity on the basis of the chromosome numbers despite any appearance the plants may have shown.

Certain interesting variations in the pollen conditions encountered between different botanical varieties of the same species are also evident from the data presented in Table 2. Some of these differences in per cents of normal appearing pollen are at least partly due to chromosome differences. This has already been pointed out in the case of *R. moschata* and some of its varieties. The relatively low per cents of normal appearing pollen found in the pentaploids *R. coriifolia* and *R. c. froebeli* (28.7 and 40.4, respectively) as compared with the much higher per cent occurring in the diploid *R. c. cinera* (77.4) offer another example of this.

In Species and Their Botanical Varieties.—In several other cases, however, a species and one or more of its botanical varieties were examined where no chromosome differences were encountered. Several examples may be cited here: (1) *Rosa multiflora* and nine of its varieties were studied; seven of the ten in this species group are known diploids, although chromosome counts were not secured on the other three varieties. It may be noted, again in Table 2, that the per cents of normal appearing pollen were high in most of these varieties, the averages being above 84 per cent in six cases; however, in the other four varieties the

per cents were 65, 47.8, 42.3, and 11.5, respectively. The variety with the most aborted pollen was a known diploid. (2) *Rosa rugosa* and five of its varieties or variants were studied. Three of these six were known diploids, but the chromosome numbers of the other three were not determined. The species and four of its varieties produced a high proportion of pollen of normal appearance. *Rosa rugosa repens,* however, had only 7.4 per cent of unaborted pollen grains. The chromosome number of this variety was not determined and it might be other than a diploid, possibly a triploid, although all the *R. rugosa* varieties thus far cytologically examined are diploids. (3) Marked differences were noted in the proportions of aborted pollen produced by *R. arvensis* (43.8%) and *R. a. sylvestris* (95.4%), both of which were diploid. Similar cases of differences might be pointed out in other species groups. On the other hand, both *R. canina* and its variety had much aborted pollen, as did the two available varieties of *R. hibernica,* while *R. spinosissima* and its two varieties and also *R. suffulta* and its variety all had high per cents of apparently normal pollen. These and other examples illustrate the range of pollen variation found within groups usually assigned to a single species. Suggestions of origin and relationship based on such data are proposed later in the general discussion.

POLLEN CONDITION CONSIDERED IN CONNECTION WITH GEOGRAPHICAL DISTRIBUTION AND CHROMOSOME NUMBERS

In Table 4 the average percentages of normal appearing pollen found among the diploid, tetraploid, pentaploid, hexaploid and other roses which occur in several approximate longitudes of Europe, Asia, and North America are shown. The figures presented in Table 4 have been summarized from the detailed data of Table 2; appendix tables used in calculating the summary figures, although not published here, are available in typed form for reference use if desired. Averages of percentages are often misleading when the different calculations are based on samples of varying numbers. Such averages appear valid when the samples are composed of approximately equal numbers, as in the present case. The average figures presented in Table 4 are often based on percentages of normal appearing pollen spread over a considerable range for the several species involved. The factors which influence the production of aborted pollen when the genus *Rosa* is considered as a whole, as discussed elsewhere in this paper, are operative also of course, within any smaller category, and are doubtless responsible, to some degree at least, for the widespread range of normal appearing pollen referred to in the preceding sentence. This variation, however, does not prevent the averages from indicating certain trends or associations that appear to exist between percentages of normal pollen of roses and (1) the several chromosome-number classes in which they occur; or (2) the

TABLE 4. A summary showing the average per cents of apparently normal pollen in the *Rosa* species and varieties examined, with particular reference to (1) the geographical origins, and (2) the chromosome constitutions of the different species studied.

Geographical source[1]	CHROMOSOME CONSTITUTION[1]										TOTALS	
	2x		4x		5x		6x		Unknown			
	No.[1]	Av.[2]	No.[1]	Av.[2]	No.[1]	Av.[2]	No.[1]	Av.[2]	No.[1]	Av.[2]	No.[1]	Av.[2]
Europe	3	53.9	6	56.6	8	16.3	2	52.0			19	38.7
Europe, N. Africa	2	69.0									2	69.0
E. Europe, W. Asia	4	71.0	12	63.0	6	22.7	5	31.2			27	49.3
Europe totals & averages	9	64.5	18	60.9	14	19.0	7	37.1			48	45.9
Asia												
Western	2	75.8	5	25.8	2	21.6			1	30.0	10	35.4
Central	11	53.9 (70.5)	1	62.9	2	29.0			1	49.6	15	50.9
Eastern	16	81.3	1	78.8							17	81.2

Geographical source[1]	CHROMOSOME CONSTITUTION										TOTALS	
	2x		4x		5x		6x		Unknown		No.[1]	Av.[2]
	No.[1]	Av.[2]	No.[1]	Av.[2]	No.[1]	Av.[2]	No.[1]	Av.[2]	No.[1]	Av.[2]		
Asia totals & averages	29	70.5	7	38.7	4	25.3			2	39.8	42	59.5
N. America												
Western	5	83.2					3	71.7			8	78.9
Eastern	2	96.8	4	90.8					1	91.9	7	92.7
Central, or all	3	94.0	5	77.8	1	85.4					9	84.0
N. America, totals & averages	10	89.2	9	83.6	1	85.4	3	71.7	1	91.9	24	84.8
Unknown	10	70.0	7	45.6	3	12.0	2	15.4	2	61.2	24	50.3
Grand totals and averages	58	72.7	41	59.5	22	22.2	12	42.1	5	58.8	138	57.6

[1] Of species and varieties studied; in case of chromosomes: 2x—diploid; 4x—tetraploid; etc.
[2] Average per cent of apparently normal pollen

several geographical groups in which they may be arranged.

Forty-eight species were studied that occur in Europe, or in Europe and neighboring territory, and 42 Asiatic and 24 American species and varieties were available for this investigation. Information as to geographical distribution has been accepted and used here as it is given by Rehder (1940) or by Index Kewensis. Data from 24 forms of known chromosome number, but of uncertain distribution, are included near the end of Table 4. A few of these, such as *R. acanthaclada,* because of their distinctive characters, were carried in our cultures by the specific name under which they were received, although these names are found neither in Rehder's Manual nor in Index Kewensis. Most of these 24 roses of unknown distribution, however, are botanical varieties of species of known dispersal. Where the origin and native home of varieties are uncertain, and where taxonomic characters, or chromosome number, or pollen condition, or a combination of these and perhaps other factors, show the existence of marked differences between the variety and the species, it is possible that the variety originated by selected mutation, or even by hybridization, at a point far removed from the area of natural distribution of the species itself.

Several facts are brought out by the summary of Table 4 pertaining to the roses included in this study. (1) Diploid roses, as a class, have higher average percentages of good pollen than do those having other chromosome groups. Only a very few of the 58 or 59 diploids examined have low per cents of normal appearing pollen. (2) Most tetraploids have rather high per cents of normal pollen, although the exceptions here are much more frequent than with diploids. The occurrence of irregular meiosis (Tackholm, 1920, 1922), as discussed elsewhere, is a cause with the unbalanced tetraploids of the Caninae. Hybridization, as discussed near the end of this paper, also probably plays a role in increasing pollen abortion in other species. (3) Nearly all pentaploids have the majority of their pollen aborted. The American *R. oreophila* is a notable, and at this time unexplainable, exception. (4) More of the hexaploids have low than have high per cents of normal pollen. Regular or irregular meiosis, as the case may be, probably account, here again, for some of the variation in the proportion of aborted pollen encountered between species. (5) In any given geographic area where all these chromosome types occur the pollen fertility of the differently-chromosomed forms most often descends from diploids, through tetraploids and hexaploids to pentaploids. (Where triploids are found, they usually have very little normal appearing pollen. Triploids are likely to have even less normal pollen than the pentaploids.) (6) If a comparison is made of the pollen condition of *Rosa* species and varieties on the basis of the several large geographic areas of dispersal, an interesting condition is noted. The

roses occurring in Europe, considered as a whole, usually produce lower per cents of normal pollen than those native to Asia, and the Asiatic species lower per cents than the American ones. Moreover, each continental group may be broken down into two or three empirical subdivisions—i.e., into species prevalent in the west, the central, and the eastern parts of a continent. Then the tendency is to find increasing amounts of normal appearing pollen as the more eastward geographical groups of any continental land mass are considered. If we start with the east Asiatic roses and consider the progressively more western groups until we come to the west coast of Europe, the noted tendency is, on the whole, quite marked and probably quite significant. If we again start with the east Asiatic roses and go eastward through the ranges of the American species the same tendency is noted, but here it is much less marked and probably of questionable significance. The discussed trends are described graphically in Figure 1. Just as this tendency is true for the several geographical groups (of convenience) as a whole, it is also apparent, with the notable exception of the western Asiatic tetraploids, for geographical groups which are composed of species of similar chromosome number. That is, the east Asiatic diploids produce more normal pollen than European ones, etc. (7) The increasing amounts of unaborted pollen found, in general, as roses occur farther eastward from western Europe may be partially explained by the chromosome numbers displayed by the species in the several areas (See points 1-5 above). With increasing distance from western Europe diploids and tetraploids tend to form a larger part, and pentaploids a smaller one, of the total species and varieties studied.

RESULTS CONSIDERED ON BASIS OF TAXONOMIC SECTIONS AND CHROMOSOME NUMBERS

In the second edition of Rehder's "Manual of Cultivated Trees and Shrubs Hardy in North America" (1940) the species of *Rosa* are arranged in four subgenera. In each of his Subgenera I, III, and IV, a single species is placed. The great majority of the species are arranged in the ten sections of Subgenus II, Eurosa. This arrangement of species by generic sections is followed here. Rehder describes 72 species in detail, but many additional "closely related" forms, hybrids, and other species, varieties and forms are mentioned—often with brief comments. Following are listed first the number of the taxonomic section, then the number of species of this section described in detail by Rehder: 1-7; 2-4; 3-8; 4-5; 5-25; 6-13; 7-4; 8-1; 9-1; and 10.1. These numbers obviously are not complete with respect to species, but do give some idea of the comparative sizes of the various sections.

TABLE 5. Per cents of apparently normal pollen in *Rosa* species, as grouped by Rehder's (1940) taxonomic sections, and arranged within these sections by chromosome numbers.

Species or variety of *Rosa*	Geographic source	Chromosome constitution 2x	3x	4x	5x	6x	8x
SECTIONS OF SUBGENUS II. EUROSA							
Section 1. Pimpinellifoliae							
foetida	W. Asia			20.0			
foetida bicolor	W. Asia			7.0			
foetida persiana	W. Asia			12.4			
grandiflora	Eur., W. Asia	74.6					
Harrison's Yellow	W. Eur., Asia			27.3			
Hugonis	C. China	84.9					
ochroleuca	Eur., W. Asia			55.9			
omiensis pteracantha	W. China	91.1					
primula	Turkestan			30.0			
spinosissima	Eur., W. Asia			86.0			
spinosissima altaica				92.8			
spinosissima hispida				76.0			
xanthina	E. Asia	67.0					
xanthina allard				27.5			
Number of forms		4		10			
Average per cent of normal pollen		79.4		43.5			
Section 2. Gallicanae							
alba	Cult. S.E. Eur.			22.9*			
centifolia	E. Cauc.			68.3	24.8		
centifolia muscosa				17.9			
centifolia salet				33.1			
damascena	Asia Minor			31.2	(28 or 35)		
damascena trigintipetala				18.2			
damascena versicolor				45.8			
gallica	S. Eur., W. Asia			56.2			
gallica conditorum				41.3			
gallica splendens				74.2			
Number of forms				10	1		
Average per cent of normal pollen				40.9	24.8		

*May be 6x instead of 4x.

Species or variety of *Rosa*	[1]Geographic source	[2]Chromosome constitution 2x	3x	4x	5x	6x	8x
		Section 3. Caninae					
canina	Europe				9.8		
canina montivega					16.7		
coriifolia	Eur., W. Asia				28.7		
coriifolia cinera		77.4					
coriifolia froebeli	Eur., W. Asia				40.4		
Desiglisei	Eur. (cent. Fr.)					35.3	
dumalis	Eur., W. Asia				9.3		
dumetorum	Eur., W. Asia, Af.				23.8		
ferox	E. Eur.,W. Asia				16.5		
inodora	Europe				4.4		
Jundzillii	Eur., W. Asia					87.9	
macrantha	France			89.8			
micrantha	Eur., Med.			43.9			
mollis	Eur., W. Asia					20.0	
montana	S. Eur., N. Am.	98.6					
Pouzini ?						12.3	
rubiginosa	Europe				28.2		
villosa recondita	Eur., W. Asia	97.8		62.4			
Number of forms		3		3	9	4	
Average per cent of normal pollen		91.3		65.4	19.7	38.9	
		Section 4. Carolinae					
carolina	U.S.	(94.8)		94.8*			
humilis (?)	E. N. Am.			92.2			
lucida	E. U.S.			94.8			
Lyonii alba	E. U.S.			91.9*			
nitida	E. N. Am.			94.8			
palustris	E. N. Am.			87.0			
virginiana	E. N. Am.			86.6			
Number of forms				7			
Average per cent of normal pollen				91.4			

*Some question as to chromosome number of these forms.

Species or variety of *Rosa*	[1]Geographic source	[2]Chromosome constitution 2x	3x	4x	5x	6x	8x
	Section 5. Cinnamomeae						
acicularis	Alaska to N. Y. N.E. Asia			78.8			
acicularis Engelmanii	N.W. U.S.	92.1					
acicularis Nipponensis	E. Asia	75.3					
adenosepala	N. Mex.	75.3					
Alberti	Turkestan				12.0		
*alpina**	Mts. of S.&C. Eur.			81.5			
amblyotis	N.E. Asia	92.9					
banksiopsis	W. China				41.5		
Beggeriana	Persia	92.3	33.9				
blanda A.	America			38.7			
blanda B or C	America	91.6					
caudata	W. China			62.9			
cinnamomea	Eur., N.&W. Asia						93.3
fendleri	N. Am.	95.7					
Giraldii	C. China	67.6					
gymnocarpa	W. N. Am.	90.3					
laxa	Turkestan			85.7			
Macounii	W. N. Am.					83.6	
nutkana	W. N. Am.					97.7	
oreophila	Colorado				85.4		
oxyodon	Cauc.			95.6			
pendulina	S. & C. Eur.			85.4			
pisocarpa	W. N. Am.	95.2					
pratincola	Cent. N. Am.			93.9			
rugosa	E. Asia	86.0					
rugosa alba		92.0					
rugosa Chamissoniana		97.6					
Seraphinii (micrantha)	S. Eur., Med.					68.8	
suffulta	Cent. N. Am.			90.2			
Webbiana	W. & C. Asia	59.2					
Willmottiae (virginiana)	W. China	91.0					
Woodsii	W. N. Am.	63.0					
Number of forms		16	1	9	3	3	1
Average per cent of normal pollen		84.8	33.9	79.2	46.3	83.4	93.3

*Some question as to chromosome number of this form.

Species or variety of *Rosa*	[1]Geographic source	[2]Chromosome constitution 2x	3x	4x	5x	6x	8x
		Section 6. Synstylae					
abyssinica	Africa	90.1					
arvensis	Europe	43.8					
arvensis sylvestris	Europe	95.4					
Fujisanensis (*Luciae* var.)	E. Asia	68.7					
Helenae	C. China	5.0					
Jackii	Korea	93.3					
Luciae	E. Asia	91.2					
maximowicziana	E. Asia	88.8					
maximowicziana pilosa	E. Asia	77.2					
moschata	S. Eur., Af., W. Asia	42.0				11.2	
moschata floribunda				92.4			
moschata grandiflora				38.4			
moschata nivea				36.9			
multiflora	E. Asia	92.3					
multiflora chenault		84.0					
multiflora grandiflora		92.5					
multiflora Iowa		47.8					
multiflora Jones		42.3					
multiflora platyphylla		11.5					
multiflora Shafter		84.6					
multiflora upright		87.4					
multiflora Welch		85.8					
sempervirens		39.4					
setigera		95.4					
*Soulieana**		22.4					
Watsoniana		47.7					
Number of forms		23		3		1	
Average per cent of normal pollen		66.5		55.9		11.2	

*Another plant, of undetermined chromosome number, had 90.4 per cent normal pollen.

	Section 7. Indicae			
gigantea	S. W. China, Burma	62.0		
Manetti	China, S. Eur., W. Asia, Afr.		60.4	
odorata	China	43.2		
*Roulettii**	China			
Number of forms		2	1	
Average per cent of normal pollen		52.6	60.4	

*Chromosome number undetermined, per cent of pollen normal: 49.6.

Species or variety of *Rosa*	[1]Geographic source	[2]Chromosome constitution 2x	3x	4x	5x	6x	8x
	Section 8. Banksianae						
cymosa	China				16.5		
	Section 10. Bracteatae						
bracteata	China (U.S.)			97.1			
	Hybrids: Sections 1 x 3						
hibernica (spinosissima x canina)	Eur., W. Asia						
hibernica glabra						4.6	
hibernica gravesii						10.5	
	Hybrid: Sections 2 x 3						
Waitziana macrantha (gallica x canina)	Europe				34.0		
	Hybrid: Sections 3 x 1						
morica (canina x (spinosissima?))					9.1		
	Hybrid: Sections 5 x 4						
michiganensis (blanda x palustris)	Michigan			98.2			
	Hybrid: Sections 5 x 7						
Lheritierana (pendulina x chinensis)	S. & C. Eur., China			22.4			
	SUBGENUS III. PLATYRHODON						
Roxburghii hirsuta	E. Asia			92.2			

[1] Abbreviations used; Af.—Africa; Am.—America; C.—Central; Cauc.—Caucasus; Cent.—Central; Cult.—cultivated; E.—East; Eur.—Europe; Fr.—France; Med.—Mediterranean; Mts.—Mountains; N.—North; N. Mex.—New Mexico; N.Y.—New York; S.—South; U.S.—United States; W.—West.
[2] Somatic chromosome numbers: 2x—diploid; 4x—tetraploid; etc.

In Table 5 the *Rosa* species studied are listed alphabetically within the several taxonomic sections of the genus under which they are grouped according to Rehder's classification. For each species the observed per cents of apparently normal pollen are arranged in columns indicating the somatic chromosome numbers of the respective species. This table also gives the general geographical occurrence of the several species. Table 5 has been arranged so as to indicate any apparent relationships between the experimentally determined pollen normality and the chromosome numbers, geographic distribution, and especially taxonomic arrangements of the roses studied.

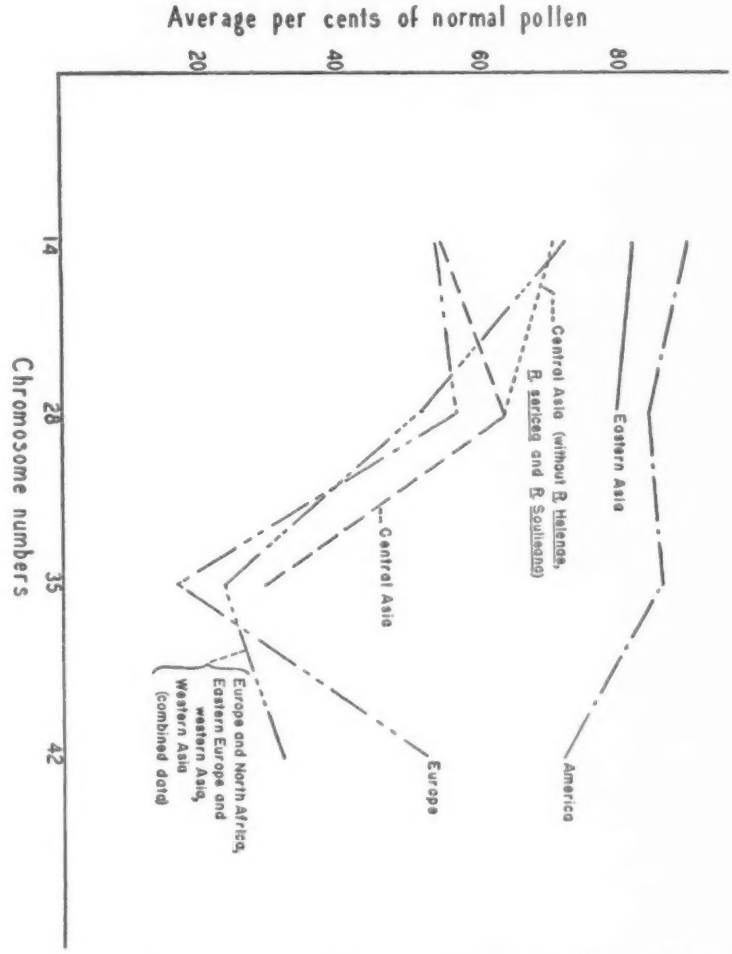

FIGURE 1. Average per cents of apparently normal pollen in different chromosome number groups of *Rosa* species from several geographical area.

Table 6 summarizes most of the data of Table 5, with the average per cents of normal appearing pollen as found among the several

chromosome-number groups, being presented by the taxonomic sections in which Rehder groups the species upon which the averages are based. Sufficient data are available for Sections 1 through 7 (where over 90 per cent of rose species are arranged) to give a reliable picture of the pollen condition encountered in the species of these taxonomic divisions.

The previously discussed tendency for association between chromosome number and per cent of normal pollen produced may be noted again, in Tables 5 and 6. Carolinae is made up, in this study, of American tetraploid, and the Cinnamomeae mainly of American and eastern Asiatic diploid and tetraploid species. Caninae, near the bottom of the list—as a group of species—in production of normal pollen, reflects the modifying effect of the large proportion of pentaploids and of several irregular hexaploids used in the study. Several of the other sections, perhaps especially Pimpinellifoliae and Gallicanae, although composed chiefly of diploids and tetraploids fail to reflect much effect of this in their pollen production. It should be noted, however, that the forms in these sections are of European or western Asiatic distribution, with the hybrid and varietal complexities common to rose derivatives of that

TABLE 6. Summary of average per cents of apparently normal pollen in *Rosa* species when grouped by taxonomic sections and by chromosome numbers.

Subgenus and section	Chromosome constitution[2]											
	2x		3x		4x		5x		6x		8x	
	No. of species	[1]Per cent normal pollen	No. of species	[1]Per cent normal pollen	No. of species	[1]Per cent normal pollen	No. of species	[1]Per cent normal pollen	No. of species	[1]Per cent normal pollen	No. of species	[1]Per cent normal pollen
Subgenus II Eurosa												
1. *Pimpinellifoliae*	4	79.4			10	43.5						
2. *Gallicanae*					10	40.9	1	24.8				
3. *Caninae*	3	91.3			3	65.4	9	19.7	4	38.9		
4. *Carolinae*					7	91.4						
5. *Cinnamomeae*	16	84.8	1	33.9	9	79.2	3	46.3	3	83.4	1	93.3
6. *Synstylae*	23	66.5			3	55.9			1	11.2		
7. *Indicae*	2	52.6			1	60.4						
8. *Banksianae*							1	16.5				
10. *Bracteatae*	1	97.1										
Hybrids: 1 x 3									2	7.5		
Hybrid: 5 x 7	1	22.4										
Subgenus III. Platyrhodon	1	92.2										

[1] Average.

[2] Somatic chromosome number: 2x—diploid; 4x—tetraploid, etc.

part of the world.

Among the first seven sections listed, two are outstanding in respect to per cents of normal pollen. Every member of the Carolinae examined had a large proportion of pollen of normal appearance. Of the thirty-three species and varieties studied in the section Cinnamomeae, in twenty-one 80 per cent or more, and in twenty-six 67 per cent or more of the pollen was of normal appearance. In the other five sections the average per cents of normal pollen were much lower; all of these sections but Indicae had a number of forms with a majority of their pollen grains aborted; and the three species studied in Indicae had but little more than half of their pollen normal in appearance.

In an earlier study dealing with crossing relations in roses (Ratsek, Flory, and Yarnell, 1940) a comparison was made of the effectiveness of species, from these seven taxonomic sections, as pollen parents. After an analysis was made of the results obtained from 201 different species crosses, involving over 5500 pollinations, the conclusion was drawn that "forms belonging to sections Carolinae and Cinnamomeae were most effective, as a group" as pollen parents. Results from the present study suggest that the production of higher per cents of normal pollen by the species of these two sections play a part, as might be expected, in their effectiveness as male parents.

POLLEN CONDITIONS IN HYBRIDS

THE MATERIAL AND THE RESULTS

Reference has been made above to interspecific crosses which were made between many of the species and individual plants available for the pollen study. The crossing work was initiated in 1937. Rose seeds are notoriously difficult to germinate. Some that do germinate do so only after many months and sometimes after several years' time. Following germination flowering maturity may not be attained for two, or even three, additional years. Consequently, a rather small number of hybrids was available from our crosses during the course of the present study.

TABLE 7. Per cents of apparently normal pollen in the F^1 hybrids of *Rosa* species crosses.

Species crossed	[1]2n numbers [2]Origin [3]Septets [4]Section	[5]Number of plants No. yrs. studied	% of normal pollen Average	Range
amblyotis x *rugosa*[6]	(14x14=?) N.E. Asia, E. Asia D(?)—C 5-5	3	68.9	60.0-76.0

Species crossed	[1]2n numbers [2]Origin [3]Septets [4]Section	[5]Number of plants No. yrs. studied	% of normal pollen Average	Range
amblyotis x *suberecta*[6]	(14x28=?) N.E. Asia, Anglia D(?)	1	85.6	
amblyotis x *xanthina allard*[6]	(14x28=?) N.E. Asia, E. Asia D-B 5-1	2	87.8	86.6-89.0
blanda x *pisocarpa*	(14x14=14) Am., W. N. Am. D-D 5-5	2, 2 yrs.	92.5	90.5-94.3
blanda x *saturata*	(14x28=?) Am., C. China D-CD 5-10	2, 2 yrs.	59.6	59.2-60.0
blanda x *Woodsii*	(14x14=14) Am., W. N. Am. D-D 5-5	1	84.0	
coriifolia froebeli x *lucida alba*	(35x28=42) Eur., W. Asia, E. U.S. ACDDE-CD 3-4	8, 4 yrs. (lowest pl.) (highest pl.)	33.9 (23.3) (53.4)	21.9-53.7 (21.9-24.7) (53.1-53.7)
coriifolia froebeli x *Wichuraiana*	(35x14=35) Eur., W. Asia, E. Asia ACDEE-AA 3-6	2, 3 yrs.	8.7	4.3-12.7
damascena trigintipetala x *lucida alba*	(28x28=28) Asia Minor, E. U.S. AC-CD 2-4	1	80.1	
	(28x28=21)	2, 3 yrs.	2.7	1.0- 4.3
	(28x28=14)	1, 2 yrs.	89.8	84.9-93.8
fendleri x *blanda*	(14x14=14) N. Am., Am. D-D 5-5	3, 2 yrs.	92.3	88.2-97.7
gallica x *blanda*	(28x14=21) S. Eur., W. Asia, Am. AC-D 2-5	4, 3 yrs.	2.0	0.6- 3.4

Species crossed	[1]2n numbers [2]Origin [3]Septets [4]Section	[5]Number of plants No. yrs. studied	% of normal pollen Average	Range
gallica x *foetida*	(28x28=21)	1	3.0	
bicolor (or *rugosa*)	(28x28=14) S. Eur., W. Asia, W. Asia AC-BD 2-1	1	38.6	
gallica x *Giraldii*[6]	(28x14=?) S. Eur., W. Asia, C. China 6-5 AC-E 2-5	2	71.8	66.2-77.5
gallica x *multiflora*	(28x14=21) S. Eur., W. Asia, E. Asia AC-A 2-6	3, 2 yrs.	3.6	1.0- 7.1
gallica x *multiflora* Welch	(see above)	7, 4 yrs.	2.8	0.4- 4.9
gallica x *nutkana*	(28x42=35 or 34) S. Eur., W. Asia, W. N. Am. AC-ADE 2-5	5, 4 yrs.	32.1	?
gallica x *odorata*	(28x14=21) S. Eur., W. Asia, China AC-? 2-7	4, 3 yrs.	1.0	.04- 2.0
gallica x *rugosa*	(28x14=21) S. Eur., W. Asia, E. Asia AC-C 2-5	2, 2 yrs.	2.1	1.3- 2.9
lucida x *multiflora* Iowa	(28x14=28) E. U.S., E. Asia CD-A 4-6	1	68.8	
lucida alba x *bella*	(28x28=28) E. U.S., N. China CD-BE 4-5	1, 2 yrs.	54.9	51.8-58.0
lucida alba x *gallica*	(28x28=28) E. U.S., S. Eur., W. Asia CD-AC 4-5	1	86.0	

Species crossed	[1]2n numbers [2]Origin [3]Septets [4]Section	[5]Number of plants No. yrs. studied	% of normal pollen Average	 Range
lucida alba x *palustris*	(28x28=35) E. U.S., E. N. Am. CD-AD 4-4	1, 3 yrs.	8.0	1.7-20.0
multiflora x *blanda* A[6]	(14x28=?)	1	63.8	
multiflora x *blanda* B	(14x14=14)	1, 2 yrs. 1	51.8	41.8-61.9
multiflora cathayensis x *blanda*[6]	Asia, W. N. Am. A-D	1	46.9	
multiflora x *rugosa*	(14x14=14) W. N. Am., E. Asia A-C 6-5	1	96.0	
rubiginosa x *multiflora cathayensis*	(35x14=35) Eur., W. N. Am. ABBCD-AA 3-6	8, 3 yrs.	8.8	2.0-21.0
rubiginosa x *Wichuriana*	(35x14=35) Eur. E. Asia ABBCD-AA 3-6	3	15.1	12.1-20.3
rugosa x *lucida alba*	(14x28=21) E. Asia, E. U.S. C-CD 5-4	4, 3 yrs.	3.4	0.4-12.7
Soulieana x *multiflora cathayensis*	(14x14=14) W. China, W. N. Am. A-A 6-6	2	88.7	85.7-91.7
Soulieana x *odorata*[6]	(14x14=14)? W. China, China A-? 6-7	3	36.8	32.1-42.4
Woodsii x *blanda*	(14x14=14) W. N. Am., Am. D-D 5-5	14, 4 yrs.	93.1	79.4-98.3
Woodsii x *multiflora*[6] Welch	(14x14=14)? W. N. Am., E. Asia D-A 5-6	2	3.1	2.3- 3.9
Woodsii x *rugosa alba*	(14x14=14) W. N. Am., E. Asia D-C 5-5	5, 4 yrs.	80.8	72.0-90.7

Footnotes on opposite page.

Table 7 presents data on the per cents of normal pollen observed in 106 plants resulting from 34 different interspecific crosses. The second column, from the left, gives information on chromosome numbers, natural geographical distribution of the parents, the "septets" represented in the parents according to Hurst's (1925, 1928) theory, and the taxonomic section to which the parents belong according to Rehder. In other words, this column furnishes information of a cytological, genetical and taxonomic nature which should give some indication of the degree of relationship existing between the parents. Plants from several of the crosses denoted by "6" were first mature enough for study in 1943. Chromosome counts were not made on those plants in 1943, and the plants have not been available to the writer since that date. This is unfortunate, especially since several of the plants which were expected to be triploid, on the basis of parental chromosome number, proved to have produced much higher per cents of normal appearing pollen than is usual for triploids. Without the hybrids of unknown chromosome number, the table shows data based on 89 plants arising from 26 crosses. It may be noted that about half of these plants are either triploids or pentaploids.

The data have been arranged in summary form in Table 8 according to the chromosome-number groups into which the several hybrids fall. This allows ready observation of some of the same general trends that were noticed in the case of the species and varieties earlier considered. The per cents of normal appearing pollen observed were again relatively high in diploids and tetraploids, quite low in pentaploids, and low in the single hexaploid hybrid. The known triploids form a much larger proportion of the hybrids than was true of the species; these have very little unaborted pollen. The information with references to the apparently tetrasomic pentaploid, $2n = 34$, plant resulting from the *R. gallica* x *R. nutkana* cross is of interest. It had 71 per cent of normal pollen, while the highest per cent for the $2n = 35$ hybrids was 21.0. A cytological comparison of meiosis of the $2n = 34$ plant, with its four sister $2n = 35$ plants, should be both interesting and revealing.

[1] Diploid chromosome numbers; of both parents and of the hybrid.
[2] Geographical sources of each parent; abbreviations used: E.—east; W.—west; S.—south; N.—north; C.—central; Am.—America; Eur.—Europe; U.S.—United States.
[3] The capital letters in the third line for each hybrid in this column indicate the "differential septets" of each parent, according to Hurst's (1925) system and designations.
[4] The numbers in the last line, for each hybrid, in this column refers to the number of the generic section, according to Rehder (1940), to which the respective parents belong.
[5] Where not otherwise indicated, the figures in this column refer to the number of hybrids which were studied from each cross. In some cases pollen of these plants was studied in more than one year, and this is so indicated.
[6] The pollen of these hybrids was examined in 1943, only. Chromosome counts were not obtained on the hybrids. Such counts—in several cases—would probably not be the 2n of 21 expected on the basis of parental counts. It would be unusual for triploids to produce the high per cents of normal appearing pollen which were observed in several of these hybrids.

EVIDENCE FROM HYBRIDS APPLIED TO THE SEPTET THEORY

The septets referred to above and in Tables 7 and 9 follow Hurst's (1925) terminology and a consideration of his theory. Hurst regards most present rose species as having descended, by loss of chromosome septets, from a now extinct hypothetical decaploid polar species. To it he assigned the formula AABBCCDDEE, each capital representing a postulated differential chromosome septet. "Since the five diploid species AA, BB, CC, DD, and EE carry only one distinct (double) septet each, they may be distinguished as the five septet species of *Rosa.*" Each septet, of course, carries a specific complement of genes which determines its own specific set of characters. Cytologically unbalanced forms are explained as having one double septet and several (two to four) single septets. (*Rosa canina,* for example, is represented with the formula AABDE.) Forms with balanced meiosis would usually have all septets dually present (AA, or AABB, or BBCCDD) under this system. Any cross resulting in hybrids with all single septets (as an AC diploid, or an ABDE tetraploid) should be completely sterile on the basis of this theory.

Several of our hybrids apparently furnish critical evidence bearing on Hurst's theory. Such data have been arranged in Table 9, where the several pertinent crosses are numbered from 1 to 155. Three of these crosses (9, 10 and 12) resulted in single individuals with chromo-

TABLE 8. Per cents of normal appearing pollen in *Rosa* hybrids, arranged by chromosome groups.

2n in F_1	No. of crosses[1]	No. of plants	Per cents of normal appearing pollen			
			average	median	modal group	range
14	10	31	80.8	89.2	86-95	38.6-96.0
21	8	27	2.6	2.75	2.7-3.0	1.0- 3.6
28	4	4	72.4	74.4		54.9-86.0
35	5	18	11.7	8.8		1.7-21.0
34	1	1*	71.0			
42	1	8	33.9			21.9-53.7

[1] As indicated in Table 7, several crosses resulted in seedlings with different chromosome numbers which increases the total of this column to 29, rather than the apparent 26.

*This plant was from one of the same crosses as the five which produced 2n=35 plants.

some numbers other than the expected ones. Speculative explanations could be made of such exceptions, but only the evidence from the other 12 crosses will be considered here as it touches Hurst's septet theory.

The Diploid Hybrids.—Crosses 1 to 10 (Table 9) resulted in mature diploid hybrids, but as explained above, crosses 9 and 10 will not be considered here.

In five cases the diploid crosses involved parents both of which have the same septet formula, according to Hurst. *Rosa blanda* x *R. pisocarpa, R. blanda* x *R. Woodsii, R. Fendleri* x *R. blanda,* and *R. Woodsii* x *R. blanda* involve only species to which the DD septet is attributed. In the cross *R. Soulieana* x *R. multiflora cathayensis* both species are listed as AA. The hybrids resulting from all these crosses would be expected to have the same double septets as their parents. They each produce high per cents of normal appearing pollen, and hence are apparently quite pollen fertile. Thus far the data appear to support Hurst's contention.

In three cases the diploid crosses involved parents to which Hurst attributed different septet formulae. These crosses are: (1) *R. multiflora* (AA) x *R. blanda* (DD), the resulting hybrid of which produces about half normal and half aborted pollen; (2) *R. multiflora* (AA) x *R. rugosa* (CC), the resulting, presumably AC, hybrid of which produced 96 percent normal pollen—the highest per cent observed among any of the hybrids; and (3) *R. Woodsii* (DD) x *R. rugosa alba* (CC), with five hybrids included in this study which varied from 72.0 to 90.7, averaging 80.8 per cent in production of apparently normal pollen. Since these AD, AC, and DC diploids are not sterile, but apparently produce an abundance of fertile pollen, they tend to oppose Hurst's thesis in certain important points at least.

The Tetraploid Hybrids.—Since cross number 12, in Table 9, is not being considered here (see above), we have the data from three remaining controlled tetraploid crosses to take into account. Both of the crosses *R. damascena trigintipetala* (AACC) x *R. lucida alba* (CCDD), and *R. lucida alba* (CCDD) x *R. gallica* (AACC), involve species with one similar double septet. Both theoretically should produce ACCD hybrids. The two do result in hybrids which produced 80.1 and 86.0 per cent of normal appearing pollen, respectively.

The remaining tetraploid cross, *R. lucida alba* (CCDD) x *R. bella* (BBEE), was made between parents in which there was complete dissimilarity of septet pairs—as attributed to them by Hurst. The resulting hybrid would be expected to have four single septets—B, C, D, and E. In two years this hybrid produced an average of 54.9 per cent normal pollen. While this is significantly below the proportion of good pollen found in the two presumed ACCD hybrids, it is still a great deal more normal pollen than Hurst postulated for the "sterile" hybrids expected

when parents with different septet pairs are crossed.

The Hexaploid Hybrid.—When *R. coriifolia froebeli* (ACDDE) was crossed with *R. lucida alba* (CCDD), eight hybrid plants resulted. These matured early and their pollen was examined in four different years. There was considerable plant variability in the pollen of these

TABLE 9. Pollen normality in *Rosa* Hybrids from controlled crosses, examined in connection with the differential septet theory.

Parent species	Formalue according to Hurst		F_1 2n	Average per cents of normal pollen in F^1
	P_1	F_1		
1. *blanda* x *pisocarpa*	DD x DD	DD	14	92.5
2. *blanda* x *Woodsii*	DD x DD	DD	14	84.0
3. *Fendleri* x *blanda*	DD x DD	DD	14	92.3
4. *multiflora* x *blanda*	AA x DD	AD	14	51.8
5. *multiflora* x *rugosa*	AA x CC	AC	14	96.0
6. *Soulieana* x *multiflora cathayensis*	AA x AA	AA	14	88.7
7. *Woodsii* x *blanda*	DD x DD	DD	14	93.1
8. *Woodsii* x *rugosa alba*	DD x CC	CD	14	80.8
9. *damascena trigintipetala* x *lucida alba*	AACC x CCDD	CC?	14	89.8
10. *gallica x foetida bicolor* (or *rugosa*)	AACC x BBDD	?	14	38.6
11. *damascena trigintipetala* x *lucida alba*	AACC x CCDD	ACCD	28	80.1
12. *lucida* x *multiflora* Iowa	CCDD x AA	(A) ACD?	28	68.8
13. *lucida alba* x *bella*	CCDD x BBEE	BCDE	28	54.9
14. *lucida alba* x *gallica*	CCDD x AACC	ACCD	28	86.0
15. *coriifolia froebeli* x *lucida alba*	ACDDE x CCDD	ACCDDE	42	33.9

hybrids. One plant averaged 53.4 per cent normal pollen. The averages for the other plants were considerably lower, the lowest being 23.3, and that for all eight plants 33.9 per cent. On the basis of the septets

formed in the parent species, according to Hurst's theory, these hybrids should have the formula ACCDDE.

The Pentaploid Hybrids.—Low per cents of normal pollen occurred in the pentaploids from five different species crosses. While occasional plants in some years had 20 per cent, or a little more, of apparently normal pollen, they would still be considered as largely pollen sterile. On this basis, along with that of formulae for hybrids and their parents, the pentaploids would present no evidence detrimental to the septet theory.

Blackhurst has recently (1949), however, summarized the results of his cytological studies on hybrids secured from crossing the pentaploid *R. rubiginosa* (ABBCD) with a total of 16 diploid, tetraploid, pentaploid, and octoploid species. His studies showed a "complete break down of parental meiotic behaviour, with a consequent formation of more than seven bivalents and a frequent occurrence of multivalent configurations." Also it was found in this work that no septets entering the crosses, on the basis of Hurst's formulae, showed complete incompatibility—as where *R. laxa* (DDEE) and *R. corifolia froebeli* (ACDEE) were used, introducing the E septet. Hurst's hypothesis, as Blackhurst points out, seems inadequate to explain these results, and genetically controlled pairing is suggested to explain the peculiarities of meiosis in the Caninae roses.

GENERAL DISCUSSION

The size of the rose genus has been briefly discussed, and one is impressed by Rehder's (1940) statement that Gandoger enumerates 4266 species from Europe and western Asia alone.

The fact of the wide distribution of the genus, coupled with the large number of species attributed to the group by some rhodologists, also tends to emphasize the variability existing in it. Part of this variability is doubtless due to the occurrence of the extensive polyploid series. For, as Stebbins (1940) has written, "among the polyploids the gaps between species no longer exist or are at least very much smaller and harder to recognize. Polyploidy, therefore, tends to break down genetic barriers and to permit exchange of genes between genetic systems that in the diploid condition are completely isolated from each other." Such a conception aids in understanding why, at least, the complexities of the genus *Rosa* are so extensive, especially in some areas of distribution. The greatest concentration of polyploid forms, and also of points of taxonomical difficulty, occurs in Europe and western Asia (see Table 4 and Figure 1). A secondary area of concentration of polyploid forms, and also of difficult problems of speciation (as shown by Erlanson's various studies) is found in North America. Sax has pointed out (1936a, 1936b) that in a number of genera of Asiatic origin more polyploid

forms of a genus occur in the New World, when it is represented there, than around the point of generic origin. *Rosa* is apparently such a genus.

THEORIES AS TO ORIGIN AND EVOLUTION OF THE GENUS

Several theories have been proposed in connection with the origin of roses. The two most general ones, applied to the genus as a whole, will be considered briefly—especially in so far as they relate to the probable area of origin, and as they are affected by the present data.

Hurst's (1925) differential septet hypothesis of origin by descent from a now extinct circumpolar decaploid species has been presented above. Part of the argument for the polar derivation is made around his Figure 175. This indicates the occurrence of all present day diploid species as being near the southern limits of the temperate zone distribution of *Rosa,* or at some longitudes, near the equator; of all octoploid species as being within or near the Arctic Circle; and of other high polyploids as falling near the octoploids, with lower polyploids being found farther south closer to the diploid ranges. Harrison and Blackburn (1927) point out many discrepancies in this picture of distribution. Hurst"s hypothesis seems to be in error at several critical points: (1) on geographic distribution of species; (2) in the distribution of chromosomes in sets of seven, and its corollary; (3) in its explanatory adequacy to account for chromosome pairing in hybrids (see Blackhurst, *loc. cit.*); (4) in explaining the occurrence of high per cents of apparently fertile pollen in hybrids, as found by Erlanson (1931) and also in this study; and in other ways. Yet it must be admitted that Hurst's theory has been most stimulating to contemporary rose cytologists, geneticists and taxonomists. This is shown in part by the amount of space devoted by Harrison, Blackburn, Erlanson and others in presenting evidence which apparently refutes the septet theory. It should also be noted, as Blackhurst has brought out, that the theory divides the genus into a small number of interrelated groups, demonstrably associated both by taxonomic traits and genetic tests, and thus has served as an admirable starting point in considering the relationship and phylogeny of the several species.

Most students of the genus, except Hurst, have held to views concerning evolution in *Rosa* which parallel thinking as to evolution in many other genera. Harrison and Blackburn (1927) set forth one of the clearest arguments both against the septet theory and for development of polyploid species from lower members of the series—in other words, for evolution by ascent, rather than by descent. Evidence is brought forward that the Cinnamomeae is comprised of a primitive group of species, and that the other sections have evolved from its species by mutation, by response to environmental influence, and by hybridization. It is pointed out that *R. Wilsoni,* a fertile hexaploid, is actually an

allopolyploid derived from a natural chromosome doubling of the hybrid between the tetraploid *R. pimpinellifolia* and the diploid *R. tomentosa*. It is suggested that other polyploid forms have developed in similar ways. This theory is less exact than Hurst's. It also fails to exhibit evident weaknesses of the type becoming more apparent in Hurst's postulations. As additional evidence bearing on *Rosa* phylogeny is produced, the more conventional school of thought is finding its argument strengthened. But many of the blocks which have broken down in Hurst's complete structure cannot be replaced from facts disclosed up to now by the more orthodox rose evolutionists.

A suggestion is made in the 1927 paper by Harrison and Blackburn on their "opinion as to the Eastern Asiatic origin of *Rosa*." No elaboration of this has been observed elsewhere in their writings. Sax (1936, *loc. cit.*) mentions *Rosa* along with other genera of Asiatic origin having polyploid representatives in North America. Tischler (1935), Muntzing (1936), Anderson and Sax (1936) and others, in considering factors resulting in the range extension of polyploids of certain genera, have pointed out that polyploids are most frequently found at the periphery of the range. Some figures presented in Table 4 with reference to chromosome number and the distribution of the species studied here have some bearing on this observation. This is summarized, with per cents being expressed to the nearest whole number, in Table 10 which gives data for the polyploid species of *Rosa* available for this study from the various areas.

TABLE 10. Geographical occurrence of the polyploid *Rosa* species used in the present study with indicated suggestion of the center of origin and distribution of the genus.

Western Asia and Europe		Eastern Asia		North America	
Polyploid Species					
Number	Per cent of total	Number	Per cent of total	Number	Per cent of total
47	81	1	6	14	58
Probable relation to center of distribution					
Periphery		Center		Periphery	

Table 10 shows that only one of the 17 species studied for the eastern Asia area was a polyploid, while a majority of the American species were polyploid as were also the great preponderance of the western Asiatic and European ones. Of the 19 forms studied which are usually regarded as being restricted to Europe all but three, or 84 per cent, are polyploid. On the other hand. of the 15 species distributed in central Asia, only 27 per cent are polyploid, and if these are considered with the eastern Asiatic species we find only 16 per cent of polyploids among the 32 species combined. A check shows that the distribution of chromosome types used in this study is rather closely representative of the case for the genus. If, for example, the approximately 185 *Rosa* species for which Darlington and Janaki-Ammal (1945) list chromosome number and geographical distribution are divided in the same way, the proportional distribution of polyploids is quite similar to that indicated in the above chart.

Thus we find the eastern Asiatic roses studied (from Korea, Japan, Kamchatka, Insular Sakhalin, eastern China, etc.), with the exception of *R. acicularis* which is a form also common to America, to be diploid. These, with few exceptions, have high per cents of normal appearing pollen. The central Asiatic roses studied (chiefly from central, western, and southwestern China), again mainly diploid, also consist for the most part of species productive of high proportions of normal pollen (the pentaploid *R. cymosa,* the diploids *R. Helenae,* our form of *R. sericea* and *R. Soulieana* offer the chief exceptions). The group of species from eastern and central Asia are also as stable and fixed, cytologically and taxonomically, as are those from any portion of the world, although approached in these respects by the American species.

Mention was made above that Harrison and Blackburn (1927) consider Cinnamomeae as the primitive section of *Rosa,* and this is not an uncommon belief among students of the group. It is the lone taxonomic section that is widely represented by species in both the Old and the New Worlds (Table 5). At least one species of the section, *R. acicularis,* occurs in both Asia and America. Polyploidy is perhaps more pronounced in this than in any other section (Table 6). The Carolinae is closely related to the Cinnamomeae; they are considered doubtfully distinct by some authors, and in most manuals available to the writer the two sections are placed adjacent to each other when both are recognized. The species of Carolinae and Cinnamomeae, as groups, have been observed to produce considerably higher per cents of normal appearing pollen than do those of other sections (Table 6). This last fact would argue for the greater genetic and cytological stability of the species of these sections.

The above facts seem, to the writer, to lead to a reasonable supposition concerning the place of origin of *Rosa,* and as well, to

furnish a fairly accurate and continuous picture of its early directions in distribution and evolution: (1) species of Cinnamomeae originated in east Asia during the early Tertiary (Harrison and Blackburn, 1927, state that fossil evidence indicates the Tertiary as the time of origin, but they do not cite the source of evidence); (2) some forms migrated westward, a few even to Europe; (3) later probably, one or more species migrated to America (over the land bridge that supposedly connected the two continents at that time; see Lindsey, 1929, after Schuchert); (4) some of the species or forms reaching America travelled south, probably aided by bird migrations and other factors, under the impetus of the cooling northern climate during the early Tertiary, while others remained in the north; (5) these groups, on a new continent, and in new and changing environments, went through a period of adaptative variability perhaps necessary for survival here, and somewhat the same procedure probably transpired in connection with the westward-tending forms; (6) the successful variants (whether modified genetically, cytologically, or in both ways) were able to cope with the new conditions, and have now had sufficient time to "stabilize" themselves; (7) from some of the more variable and possibly less successful "fringe" forms, species which we now place in other sections had their origins, and variation and speciation are still proceeding apace among some of the more recent groups; and (8) evolution has proceeded further, into more diverse directions, and has resulted in more problems of speciation and hybridization in the forms which migrated westward into Europe than has been the case with the eastward migrants.

The confusing situation in the Caninae roses has been given attention by several workers. Most rose geneticists now consider the unbalanced Caninae group to have arisen by hybridization, either by repeated crosses between different types of diploid species or by a cross between hexaploid species. After this, as Huxley (1942) observes, "the special peculiarities of the system must have arisen adaptatively." Apomixis of the majority of the Caninae (Tackholm, 1920, and others) has been accepted by most geneticists, for a number of years, as an additional (probably resultant) complication in this group. Blackhurst (1949), however, now believes the supposed apomictic forms to be sexually reproducing groups which maintain their maternal identity by the large proportion of characters necessarily inherited through the egg cell. Perplexity is added to genetic and taxonomic considerations involved here in either case.

VARIATION IN FERTILITY IN ROSE HYBRIDS

The whole species problem in roses is complicated by ease of crossing within the genus. Good (1947) cites *Rosa* as a genus "particularly rich" in interspecific hybrids. Hybridization is easily accomplished

between at least some species of all different sections tried under controlled conditions (Ratsek, Flory, and Yarnell, 1940), and seems to occur between at least some species of all taxonomic sections which overlap in natural distribution. Hybrids between many species are surprisingly fertile, as is indicated for the pollen side of the picture by the data in Table 7. Often apparently fertile hybrids are known to be derived from closely related parents, but in other cases the relationship is either closer than is usually so attributed, or similar blocks of genes have been paired by chance combination more often than probability would indicate possible.

In contrast, we find many roses usually or often given specific status, which exhibit characteristics frequently associated with hybridity. Among these is the occurrence of significant amounts of aborted pollen. From her studies on chiefly North American wild roses Erlanson (1931) concluded that a plant with over 30 per cent aborted pollen grains, especially if it set little or no fruit, was probably a hybrid. Converse reasoning could not be followed concerning nonhybridity, as is amply borne out by the experiments with hybrids reported here.

This conclusion concerning hybridity may be profitably applied to our data from individual species as summarized in Table 2. Practically all the pentaploids studied produced less than 30 per cent normal pollen; of the four exceptions three did not appreciably exceed this proportion. Only *R. oreophila* with 85.4 per cent was really notable for its apparent pollen fertility; this case seems worth re-examining from several standpoints. The data on pollen sterility support, with the one exception, the usual theories as to hybridity in pentaploids. Among the more than forty tetraploids for which data have been presented in Table 2, eleven or twelve were found to have less than 30 per cent normal pollen. One of these, *R. alba* L., is suggested by Rehder as probably being a product of *R. corymbifera* x *R. gallica* Six of the others are botanical varieties, at least several of which have been suspected on taxonomic grounds of being species hybrids with a preponderance of their phenotypic characters similar to the parental species to which taxonomists have assigned them. Only five of the 58 diploids studied produced less than 30 per cent normal appearing pollen. To one of these, *R. Lheritieriana* Thory, Rehder assigns hybridity (*R. pendulina* x *R. chineisis*). Another is a botanical variety of *R. multiflora* which has been suspected of a hybrid origin. The other three "species" are possibly species hybrids exhibiting an exceptional number of characters of the several parental species under whose names they are successfully masquerading. Similar consideration might be given the few species in the other chromosome groups, but the resulting conclusions would not be altered thereby.

It seems obvious that hybrids in *Rosa* between closely related species, or from crosses which introduce significant numbers of alleles

from more distantly related species, may produce varying amounts—even up to almost 100 per cent—of normal appearing pollen. More than one "good" species is probably hiding its hybrid origin at least in part because of its fertility. On the other hand, large amounts of aborted pollen seem to be a definite indication of hybridity. It is a character readily observed, and is a very useful adjunct to taxonomic and chromosome evidence in discerning hybrids exhibiting this pronounced pollen condition.

ACKNOWLEDGMENTS

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SUMMARY

Data available from other workers on pollen abortion in *Rosa* species is presented, mostly in tabular form. This, together with the present new data, brings together in one place most of the reported information regarding pollen condition in roses.

Per cents of apparently normal pollen for 95 species and about 55 botanical, horticultural and cytological variants of *Rosa* were determined over the five year period of the present study. Pollen studies, with very few exceptions, were made on plants of determined chromosome number.

Only slight seasonal variation in pollen condition was encountered in the plants of most species and hybrids. There was often, but not always, a marked variation in the pollen condition of (1) chromosomal variants of the same species, and (2) species and certain of their botanical varieties.

Considered in groups, on the basis of chromosome numbers the average per cents of normal pollen decreased from diploids, through

tetraploids and hexaploids to pentaploids. The single octoploid species was high, the several triploid ones very low, in per cents of normal pollen. In general, western Asiatic and European species have, probably significantly, lower per cents of normal pollen than do those native to eastern Asia, while American species produce somewhat higher per cents of unaborted pollen than do the eastern Asiatic ones. Species belonging to the taxonomic sections Carolinae and Cinnamomeae were outstanding, as groups, in the per cents of normal pollen produced. This is correlated with the known pollen effectiveness of these groups in actual species crosses.

Per cents of normal pollen produced by 106 hybrid plants resulting from 34 different interspecific crosses were determined. Normal pollen produced by hybrids arranged in similar chromosome groups conformed quite well with the observations made with respect to species and varieties. In several cases hybrids resulting from crosses between species supposed to be quite diverse genetically, and remote taxonomically, produced pollen with surprisingly high per cents of apparent normality. Evidence of this type serves to refute the validity of Hurst's differential septet theory of evolution in *Rosa*.

Other arguments against, together with advantages of, the septet theory are pointed out. The information on the pollen condition in *Rosa* species is combined with that from numerous other sources, and its bearing on phylogeny is considered. Arguments from various sources for the theory that polyploids have arisen by ascent, beginning with diploids, are presented. On the background of available evidence a step by step hypothesis is outlined concerning the place of origin of *Rosa* (in eastern Asia) from the primitive Cinnamomeae, and its distribution and evolution both to the west (as far as Europe) and to the east (in America).

Hybridization is one of the main factors which has helped to prevent the classification of *Rosa* into species of the same value as those of most other genera. The part that hybridity, with its resulting varied and confusing fertility, has and is playing in the speciation of roses is discussed.

LITERATURE CITED

ANDERSON, E. AND KARL SAX 1936—A cytological monograph of the American species of *Tradescantia*. *Bot. Gaz.* 97: 433-476.

BALDWIN, J. T., JR. 1939—Chromosomes from leaves. *Science N. L.* 90: 240.

BLACKBURN, K. B. AND J. W. H. HARRISON 1921—The status of British

rose forms as determined by their cytological behaviour. *Ann. Bot.* 35: 159-188.

BLACKHURST, H. T. 1949—Cytogenetic studies on *Rosa rubiginosa* and its hybrids. *Proc. Amer. Soc. Hort. Sci.* 52: 510-516, (1948).

BLAKESLEE, A. F. AND J. L. CARTLEDGE 1927—Sterility of pollen in *Datura*. *Mem. Hort. Soc. N. Y.* 3: 305-312, (1926).

CREPIN, F. 1889—Recherches sur l' etat du developpement de pollen dans diverse especes du genre *Rosa*. *Bull. Soc. Bot. Belg.* 28(2): 114-125.

COLE, RUTH D. 1917—Imperfection of pollen and mutability in the genus *Rosa*. *Bot. Gaz.* 63: 110-123.

DARLINGTON, C. D. AND E. K. JANAKI-AMMAL 1945—Chromosome Atlas of Cultivated Plants. *G. Allen and Unwin, Ltd.* Aberdeen. 397 pp.

ERLANSON, E. W. 1929—Cytological conditions and evidence for hybridity in North American wild roses. *Bot. Gaz.* 87: 443-506.

———— 1931—Sterility in wild roses and in some species hybrids. *Genetics* 16:75-96.

FLORY, W. S., JR. 1940—Examination of rose pollen and chromosomes. *Texas Agri. Exp. Stat. Ann. Rpt.* 53: 28.

———— 1941—Rose investigations: Examination of pollen. *Texas Agri. Exp. Stat. Ann. Rpt.* 54: 53-54.

FLORY, W. S., JR. AND M. L. TOMES 1943—Studies of plum pollen, its appearance and germination. *Jour. Agri. Res.* 67: 337-358.

FOCKE, W. O. 1881—Die Pflanzen-Mischlinge. *Verl. Gebr. Brontraeger*, Berlin. 569 pp.

GOOD, RONALD 1947—The Geography of the Flowering Plants. *Longmans, Green and Co.*, London, New York, Toronto. 403 pp.

HARRISON, J. W. H. AND K. B. BLACKBURN 1927—The course of pollen formation in certain roses, with some deductions therefrom. *Mem. Hort. Soc. N. Y.* 3: 23-32, (1926).

HEILBORN, O. 1928—Zytologische Studien uber Pollen-sterilitat von Appelsorten. *Svensk. bot. Tidskr.* 22: 185-199.

HURST, C. C. 1925—Chromosomes and characters in *Rosa* and their significance in the origin of species. *Experiments in Genetics.* 534-550.

———— 1928—Differential polyploidy in the genus *Rosa* L.

Verh. V. Inter. Kongr. Vererb. Berlin. 2: 866-906, (1927).

HUXLEY, JULIAN 1942—Evolution—The Modern Synthesis. *Harper and Brothers,* New York and London. 645 pp.

LINDSEY, A. W. 1929—Textbook of Evolution and Genetics. *Macmillan and Co.,* New York. 459 pp.

LITTLE, T. M. 1942—The distribution of North American rose species. *Amer. Rose Ann.* 37-49.

MUNTZING, A. 1936—The evolutionary significance of autopolyploidy. *Hereditas.* 21: 263-378.

RATSEK, J. C., S. H. YARNELL, AND W. S. FLORY, JR. 1939—Crossing relations of some diploid species of roses. *Proc. Amer. Soc. Hort. Sci.* 37: 983-992.

RATSEK, J. C., W. S. FLORY, JR., AND S. H. YARNELL 1939—Rose investigations: breeding; chromosome counts; pollen studies. *Texas Agri. Exp. Stat. Ann. Rpt.* 52:31-32.

———————— 1940—Crossing relations of some diploid and polyploid species of roses. *Proc. Amer. Soc. Hort. Sci.* 38: 637-654.

REHDER, A. 1940—Manual of Cultivated Trees and Shrubs Hardy in North America. *Macmillan and Co., (Rev. Ed.),* New York. 996 pp.

SAKAMURA, T. AND I. STOW 1926—Ueber die experimental veranlasste Entstehung von keimfahigen Pollenkornern mit abweichenden Chromosomenzahlen. *Jap. Jour. Bot.* 3: 111-137.

SAX, KARL 1936a—The experimental production of polyploidy. *Jour. Arn. Arb.* 17: 153-159.

———————— 1936b—Polyploidy and geographic distribution in *Spirea. Jour. Arn. Arb.* 17: 352-356.

STADLER, L. J. 1931—The experimental modification of heredity in crop plants. I. Induced chromosomal irregularities. *Scient. Agr.* 11: 557-572.

STEBBINS, G. L., JR. 1940—The significance of polyploidy in plant evolution. *Amer. Nat.* 74: 54-66.

STOW, I. 1926-1927—Cytological study on pollen sterility in *Solanum tuberosum. Jap. Journ. Bot.* 3: 217-238.

TACKHOLM, G. 1920—On the cytology of the genus *Rosa. Svensk. bot. Tidskr.* 14: 300-311.

———————1922—Zytologische Studien uber die Gattung *Rosa*. *Acta Horti Bergiana* 7: 97-381.

TISCHLER, G. 1935—Die Beteutung der Polyploidie fur die Verbreitung der Angiospermen. *Bot. Jahrb.* 67: 1-36.

WILMOTT, ELLEN. 1914—The Genus *Rosa*. *John Murray*, 2 *Vols*.. London.

YARNELL, S. H. 1940—Rose cytology. *Texas Agri. Exp. Stat. Ann Rpt.* 53: 28-29.

YARNELL, S. H. AND H. T. BLACKHURST 1941—Rose investigations: Cytological studies. *Texas Agri. Exp. Stat. Ann. Rpt.* 54: 53.

New Constructions for the Conic Sections

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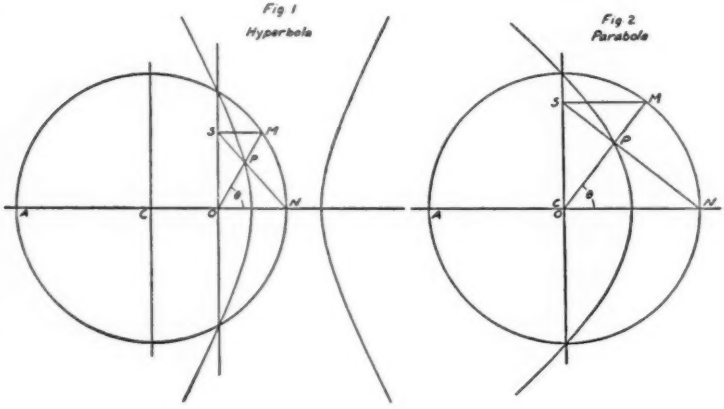
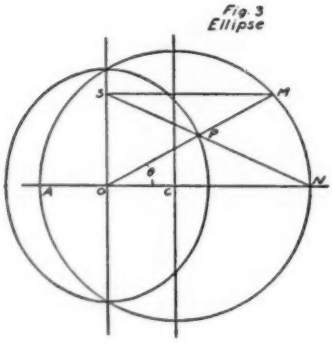
It is the purpose of this note to describe new and interesting constructions that permit the hyperbola, parabola and ellipse to be derived from the circle and to substantiate the identity of the curves with an analytical proof.

GENERAL METHOD

Draw a circle and at any point O on a diameter AN erect a perpendicular as in Figures 1, 2, and 3. Connect O with any point M on the





circumference and draw MS parallel to AN. The locus of P, the intersection of OM and SN, will be

(1) an hyperbola when O lies between the center C and N
(2) a parabola when O and C coincide and
(3) an ellipse when O does not lie between C and N.

The three cases are illustrated by Figures 1, 2 and 3, respectively.

PROOF

In the similar triangles OPN and MPS of Figures 1, 2 and 3,

$$\frac{OP}{PM} = \frac{ON}{SM} \tag{1}$$

Let O be the origin of polar coordinates r and Θ and let OP = r and OM = R. Let the radius of the circle be a and let OC = b, so that

$$PM = R - r$$
$$ON = a + b$$
$$\text{and } SM = R \cos \Theta$$

Substituting these values in Equation 1,

$$\frac{r}{R - r} = \frac{a + b}{R \cos \Theta}$$

from which

$$r = \frac{(a + b)\,R}{R \cos \Theta + a + b} \tag{2}$$

The equation of the circle, referred to polar coordinates, is

$$R^2 - 2\,R\,b \cos \Theta + b^2 - a^2 = 0.$$

Solving this latter equation for R, substituting the value so found in Equation 2 and replacing $\cos \Theta$ by $\frac{x}{\sqrt{x^2 + y^2}}$ and r by $\sqrt{x^2 + y^2}$ it is possible to effect a transformation from polar to rectangular coordinates so that the general equation becomes

$$y^2 + \frac{4b}{a + b}x^2 + 2(a - 2b)x = a^2 - b^2 \tag{3}$$

Equation 3 reduces to expressions for hyperbolas, parabolas and ellipses when b takes the values required by the various positions of O. Thus, when O lies between C and N, say, at the midpoint, b = —a/2 and the general equation becomes

$$\frac{(x - a/2)^2}{a^2/16} - \frac{y^2}{a^2/4} = 1$$

which is readily recognized as the equation of an hyperbola, Figure 1.

When O coincides with C, b = O, and the equation becomes

$$y^2 = a^2 - 2ax$$

which is the equation of a parabola, Figure 2.

When O does not lie between C and N but lies, say, midway between A and C, b = a/2 and the general equation reduces to

$$\frac{x^2}{9a^2/16} + \frac{y^2}{3a^2/4} = 1$$

which is the familiar form of the equation of an ellipse, Figure 3. Incidentally, to produce an ellipse, O need not lie within the circle.

Hydrogenation Studies on Midlothian Coal

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Coal, petroleum, and natural gas are no longer the separate and unrelated industries they once used to be. Their close molecular relationship has been recognized by technical men throughout the world and has resulted in the production of liquid fuels from coal and gas on an industrial scale. The trend is toward the day when consumption of coal as a solid fuel may not be commercially feasible. A rapid change in the use of fuels is at hand, stemming from the revolutionary new things being accomplished with coal. This is inevitable, because the United States has a super abundance of coal reserves while the reserves of petroleum and natural gas are small by comparison. If our natural petroleum supply were to last another 50 years, which is more than double the life of our proved reserves existing to date, it would account for only 0.4 per cent of the national total of all fuel reserves. Excited geographers, for many years, have called attention to the fact that our reserves of petroleum crudes will "soon" be depleted, while oil company men have complacently called attention to the records of past and present discoveries. Military and civilian nationalists have foreseen the necessity of being self-sufficient in liquid fuel production and production men have said, "it costs too much". However, today much research and development is being carried on by both industry and government in an effort to establish an economically sound synthetic fuel industry in the United States.

HISTORY OF COAL HYDROGENATION

The history of coal hydrogenation may be considered as being divided into two definite periods, an early period before the advent of the internal combustion engine in which the interest was more from an academic standpoint, and the present or modern period in which the interest has been from an economic and national security standpoint. The "have not" European powers in the early part of this century fostered the development of the synthetic liquid fuel industry, primarily striving to become self-sufficient in the interest of national security.

Early Period.—In 1869, Berthelot (Beuschlein and Wright, 1932) showed that coal could be hydrogenated to produce oils and tars by treating coal samples with hydroiodic acid at a temperature of 270° C. for a period of 24 hours. This reaction yielded a 60 per cent conversion (by weight of coal) to a heavy naphthenic oil. Further experiments with wood gave similar results with lower yields. Coke and graphite were found to be nonreactive under the same conditions.

Modern Period.—Fischer and Tropsch (Genet, 1947) extended the

work of Berthelot to include various ranks of coal and found that the degree of liquefaction increased with a decrease in the rank of the coal from anthracite to lignite and peat.

In 1913, Bergius (1926) liquefied coal using hydrogen under pressures ranging up to 200 atmospheres at temperatures of 400 to 700° C. Bergius subsequently found that the addition of catalysts to the reaction aided the liquefaction of the coal. The patented Bergius process is today the basis for many commercial hydrogenation plants for the production of motor fuels, especially in Germany. By 1933, it became apparent that Germany could no longer import petroleum crudes in quantities necessary for her requirements, and a large scale program for the development of a synthetic liquid fuel industry was begun. This program led to the construction of ten major hydrogenation plants that supplied 85 per cent of Germany's aviation gasoline during World War II.

On the other hand, the United States, blessed with a bountiful supply of domestic natural petroleum crudes, did not become interested in synthetic liquid fuels, except from an academic standpoint, until as late as 1936. Up to this time, discoveries of new petroleum fields were for the most part increasing more rapidly than the needs for motor fuel, but with the advent of the highly mechanized World War II and the subsequent heavy demand on our domestic crude reserves, considerable attention has been brought to bear on the possibility of establishing a synthetic liquid fuel industry in America. Early in 1944, the 78th Congress authorized the appropriation of $30,000,000 for the construction and operation of pilot plants to produce synthetic fuels from coal, oil shales, agricultural and forestry products, and other substances to obtain the necessary cost and engineering data for the development of such an industry. The pilot plant for the hydrogenation of coal by a modified Bergius process at Louisiana, Missouri, put into operation in May, 1949, is the latest unit in the development program recommended by Congress.

VARIABLES AFFECTING COAL HYDROGENATION

Storch (1937a) described the mechanism of the coal hydrogenation reaction as taking place in three stages. In the first stage, oxygen, sulfur, and nitrogen are removed. The second stage consists of the addition of hydrogen to both the dissolved and the solid components of the coal by transfer through the liquid vehicle. Finally, the third stage is the reduction of the dissolved components by hydrogen absorption. Because coal is a heterogeneous substance composed of various types of compounds, all three of the stages of the reaction proceed simultaneously at varying rates depending upon the pressure used, the time and temperature of the reaction, the type of catalyst and vehicle, the particle size of the coal, and the rank and petrographic constituents of the coal.

Pressure.—The obvious effect of pressure upon the hydrogenation

reaction is to increase the concentration of hydrogen in the reaction. Storch (1937a) has refuted the theory that pressure is necessary to prevent repolymerization and reverse hydrogenation reactions. Since the fact that hydrogenation reactions proceed with greater ease at pressures of 200 atmospheres is definitely proven, Storch suggested that other factors governed by the hydrogen pressure must control the rate of reaction.

It is believed (Hydrogenation of Coal, Round-Table Discussion, 1944, and Storch, 1937a) that high pressure is necessary to keep the liquid vehicle in the liquid state, to increase the amount of dissolved hydrogen in the reaction mass, to effect a more rapid regeneration of active hydrogen carriers, to prevent reversible reactions, and to orient certain groups produced by pyrolysis.

Time.—The general effect of time of contact upon the hydrogenation reaction is interrelated with other rate controlling variables. Under any given set of conditions, the time of contact controls the extent of the reaction. Hirst (1941) showed that increases in the time of reaction decrease the yield of oils and tar and increase the yield of gaseous products and the consumption of hydrogen. As less extreme conditions are imposed upon the reaction, the rate of reaction is slowed to the extent that the time must be increased in order to achieve perceptible results.

Temperature.—According to Storch (1937a), the effect of temperature upon the hydrogenation reaction becomes very pronounced at about 400° C. at which temperature the active pyrolysis of most coals occur. This is not to say that variations of temperature in the lower ranges have no effect upon the rate of reaction because, even in the lower ranges, changes in temperature are accompanied by corresponding changes in the rate of reaction. At high temperatures the adsorption of bituminous materials upon the surface of contact catalysts is greatly reduced (Storch, 1935).

Catalyst.—In early investigations (Berl, 1941, Sprunk, 1935, and Storch, 1945) the beneficial effect of the catalytic action was definitely proved, but the existence of many possible catalysts to promote the hydrogenation reaction proves that little conclusive knowledge exists concerning the nature of the catalytic activity. Warren (1939) showed that the catalytic effect in not an independent variable; however, to limit catalytic action to a definite compound or class of compounds is difficult. It has been pointed out that the heterogeneous nature of coal leads to the existence of many simultaneous reactions during hydrogenation, each of which may be affected by the presence of a different catalyst. Therefore, for any given coal, the optimum catalyst must be

[1] Akabori, 1929, Asbury, 1934 and 1936, Berl, 1941, Beuschlein and Wright, 1932 and 1933, Beuschlein, Wright and Christensen, 1932, Beuschlein, Wright and Williams, 1934, Bognar, 1937, Doldi, 1939, Fein, 1939, Hurst, 1939, Tupholme, 1936, and Warren, 1939.

determined experimentally.

Vehicle.—Fisher and Eisner (1937) proved that the suspension of the coal particles in a vehicle enhances the hydrogenation reaction. Extensive tests carried out by a number of investigators[1] proved conclusively that tetrahydronaphthalene, "tetralin", is the best vehicle available for coal hydrogenation. From an economic standpoint the heavy oil from coal hydrogenation is the most practical vehicle, and in commercial processes, this oil is recycled to make up the new suspension of the inlet coal (Tupholme, 1936).

Boomer (1935) and Pott (1933) proved that tetralin acts as a donor of hydrogen as well as a carrier of hydrogen. Actually, Doldi (1939) suggested that the mechanism of hydrogen transfer consists of the loss of hydrogen by tetralin to the components of the coal followed by a subsequent rehydrogenation of the depleted tetralin. Kiebler (1940) and Hirst (1941) reported that tetralin has a pronounced solvent action upon coal.

Particle Size of Coal.—Since the rate of any diffusion process depends upon the surface area across which the diffusion must take place, it follows that the particle size of the coal would govern the rate of the hydrogenation reaction to a considerable extent. Storch (1935) and Warren (1937) showed that this postulate is only partially true, and they point out that the solvent action of the vehicle overcomes the effect of further size reduction at about 80-mesh U. S. standard screen. From minus 10-mesh to 80-mesh, the reaction rate was increased by the reduction in the size of the particles. From minus 80-mesh to 325-mesh, the reduction in particle size had no appreciable effect upon the rate of reaction or upon the degree of liquefaction. In industrial hydrogenation plants, the coal is reduced to about 100-mesh both for the purpose of speeding the reaction and for the separation of foreign material. Also, coal in this size range has proved satisfactory in the preparation of suspensions which must be pumped at high pressure.

Rank of Coal.—According to Lowry (1934a, 1934b), it has been generally agreed that the ease of hydrogenation of coal increases as the rank of coal decreases. Since coal is such a heterogeneous material, its properties cannot be correlated on the basis of ultimate analysis alone. Other factors which must be considered in the determination of the properties of a coal are the geological origin, age, degree of coalification, and petrographic constituents.

Petrographic Constituents.—Fieldner (1944) reports that the petrographic type affects the amenability of a coal to hydrogenation even more than rank. Studies on the petrography of various coals were made shortly after 1920 in Germany, England, and the United States. In this country, the U. S. Bureau of Mines has adopted the work of Reinhardt Thiessen who pioneered in coal petrography in the United States.

According to Thiessen (1935, 1937), coal consists of three classes of petrographic constituents, anthroxylin, attritus, and fusain. Fisher (1939, 1942) found that anthroxylin is completely liquefied by hydrogenation, while opaque attritus contains from 20 to 60 per cent material resistant to hydrogenation, and fusain is almost completely resistant to hydrogenation.

ECONOMY OF COAL HYDROGENATION

The destructive hydrogenation of coal for the commercial production of motor fuels and lubricants is employed by those countries poor in domestic crude petroleum reserves. The synthesis of petroleum from coal is not yet economically feasible where natural petroleum crudes are available in quantities sufficient to meet the demand for petroleum products (Storch, 1937b). The present domestic crude reserve situation in the United States has led to much government and private subsidy of research in this field (Schroeder, 1943).

Gasoline Costs.—Stanolind Oil and Gas Company (Solliday, 1949) recently completed an analysis of the current competitive position of liquid fuels from coal and oil shale as compared to those from oil and natural gas.

The analysis of the costs showed that liquid fuels from coal and shale cannot compete successfully with products from petroleum in today's markets. The costs are based on processes considered to be technically feasible today. The direct costs including the costs of mining, manufacture, and transportation to a common marketing area in the making of a gallon of gasoline from the various raw materials are not far different. Direct costs alone do not provide the true basis for comparison, and when investment costs are included, the total costs of liquid fuels from the various sources vary considerably. The investment costs here include 14 per cent per year return on investment to take care of depreciation and taxes and to pay off the investment in 10 years. It will be noted that on this basis gasoline from crude costs 12.2 cents per gallon, from natural gas 15 cents, from oil shale and bituminous coal 22.5 cents, and from sub-bituminous 27.6 cents. The cost to the consumer would be still higher, approximately 15 cents per gallon above the manufacturing costs. Thus, the retail price of liquid fuel from coal or oil shale would range between 40 and 50 cents per gallon. Notwithstanding the high costs encountered in the production of a gallon of synthetic fuel in today's market, research must be continued so that in the time of future demands and resulting deficits in natural petroleum crudes, the synthetic fuel industry will be able to bridge the gap as economically as possible.

Total Daily Demand for Petroleum. (Solliday, 1949).—The present daily demand for petroleum is 5,900,000 barrels. A forecast of our

future demands is made by considering certain significant trends in our economy. These major trends include the growth of our population, the increasing use of automobiles, trucks, buses, and other motor vehicles, our rising standard of living, and the decentralization of cities and industries. Our daily demand for petroleum and petroleum products by 1975 will have reached approximately 9,100,000 barrels while our domestic supply from natural sources will approximate but half of this demand. The remainder of the demand must be accounted for from imports and from synthetic liquid petroleum and if we are to be self-sufficient to take care of any emergency, the entire deficit must come from synthetics.

MIDLOTHIAN COAL

It is apparent that in a few years our natural petroleum reserves must be augmented by petroleum from other sources and every possible source of reserves must be investigated. With that fact in mind, research on the hydrogenation of Midlothian coal has been under investigation for the past three years at the Virginia Polytechnic Institute. The research has been carried out in conjunction with the graduate program and has progressed in three stages to date: first, low pressure hydrogenation studies, second, hydrogenation under pressures up to 1200 pounds per square inch, and third, hydrogenation under pressures from 1200 to 3400 pounds per square inch.

Richmond Basin.—An excellent brief description of the Richmond Basin, which contains the Midlothian coal, and the analysis of the coal is to be found in "Virginia—Economic and Civic" survey of 1933 which states,

> "The Richmond Basin lies about ten miles west of Richmond and includes approximately 190 square miles in Amelia, Powhatan, Goochland, Chesterfield, and Henrico counties. The rocks which carry the coal, known as the Newark series, are Triassic age, and are surrounded and underlain by pre-Cambrian schists and gniesses. This was the first coal field to be developed in the United States, and Virginia coal was sold in Pennsylvania before the Revolutionary War. The coal was actively mined for more than 100 years, but in recent years it has not been operated.
>
> Structurally, the area is believed to be a basin: the coal outcrops around the border, and the beds and associated rocks appear to dip toward the center. The find of coal at a depth of 2,330 feet in drilling about one mile from the eastern margin of the field supports this theory. In common with other Newark areas in eastern United States, this area is much faulted, a characteristic which, with local folding, raises doubt as to the value of the dips in proving the synclinal structure.
>
> The total thickness of the Newark sediments is about 2,500 feet. The productive beds lie in the lower part of the series, and consequently occur probably at considerable depth in the center of the field. The number of beds varies from two to five, three being the rule in areas which have been worked. Extraordinary thicknesses are reported, but owing to variation in number and thickness of beds and to uncertainty as to distribu-

tion of the coal, no very reliable estimate of reserves can be made. Assuming an average thickness of twelve feet of mineable coal over an area of 150 square miles, there would be over 1,000,000,000 tons.

The coal varies rather widely in percentage of volatile matter and fixed carbon, ranging from 18 to 36 in volatile matter and from 70 to 59 in fixed carbon. These figures show the rank to range from semibitumious to high-volatile bituminous. In places the coal has been effected by igneous instrusions to such an extent that it has been party coked in the ground. As this is the only bituminous coal so near the Atlantic seaboard, it again should be of economic value in the future, but at present it can hardly compete with the western Virginia and West Virginia coals, which lie in flat, undisturbed beds above drainage."

Thus, was this description and economy picture drawn several years before hydrogenation became of importance in the fuel industry. It may be that in the not too distant future, with the continued improvements in the technical "know how" of the liquefaction process, Midlothian coal, with its ideal composition and structure for hydrogenation, and its nearness to the Atlantic seaboard will again be of economic importance.

Results of Investigations.—The results of the investigations carried out at low pressure by H. A. Scott (1947) indicated that Midlothian coal passing a 100-mesh U. S. screen, could be liquefied to the extent of 31.3 per cent by hydrogenation at atmospheric pressure and 185° C. after 72 hours reaction time in a tetralin vehicle using stannous sulfide as a catalyst. The liquid product produced consisted of approximately 50 per cent light oil, boiling below 200° C., 20 per cent middle oil, boiling between 205 and 235° C., and 30 per cent heavy oil or tar residue. The light oil produced by the extraction of the coal by tetralin in an inert atmosphere and without a catalyst consisted of more than 95 per cent aromatic compounds.

G. R. F. Genet, Jr. (1947) undertook to study the effect of pressure up to 1200 pounds per square inch on the degree of liquefaction of the same type of coal as used by Scott. The results of Genet's work indicate that a maximum liquefaction of 80.8 per cent can be obtained by using a pressure of 1200 pounds per square inch, a temperature of 385° C., 8 hours reaction time, tetralin to coal ratio of 3.8 to 1, and a 1 per cent stannous sulfide catalyst, based on the weight of coal.

M. F. Jenny (1949) extended the work of Genet to include the effect of pressures up to 3400 pounds per square inch on the degree of liquefaction. He also made studies on the optimum coal particle size to use in the hydrogenation studies at the higher pressure. In his findings, he reports that a maximum liquefaction of 89.5 per cent was obtained using a pressure of 3400 pounds per square inch, a temperature of 385° C., 3 hours reaction time; and the same quantities of vehicle and catalyst as used by Genet. The optimum particle size of the coal was found to be in the range of 149 to 104 microns diameter, or those passing

a 100-mesh U. S. standard screen but retained on a 140-mesh screen. It was found that when the tar fractions of products from previous tests were used as the vehicle for hydrogenation, the degree of liquefaction was decreased to 70 per cent.

Midlothian coal may be considered very active and have excellent possibilities as a raw material for hydrogenation to liquid products in view of the fact that the latest pilot plant (Kastens, 1949) at Louisiana, Missouri, is using 10,300 pounds per square inch pressure to effect the necessary conversion. The maximum conversion reported in the literature by the Bureau of Mines is 92 per cent. The high pressures being used and the conversions reported on other coals indicate further that Midlothian coal should definitely be considered, in light of the work of Scott, Genet, and Jenny, as a promising raw material.

Petrographic Type.—The petrographic type of coal has been shown to be a good indication of the chemical activity of most coals. To determine the petrographic type of Midlothian coal, the empirical relationships derived by Fisher (1938) were used. From this determination, Midlothian coal conformed more closely to the data for bright and anthroxylon type coal. This type is the most chemically reactive type and is composed of coalified plant parts. According to Biggs (1937), the reactive material in an anthroxylon type coal is contained inside a relatively inert cell wall which must be penetrated by the reacting material before an appreciable reaction takes place. This cell wall may be disintegrated by physical size reduction of the coal to micron size or by extreme conditions of reaction. The activity of the Midlothian coal may be explained on the basis of the Bigg's theory by the possibility that the cell structure of the plant life prevalent during the Triassiac Age (the fern type plant) was of a weaker nature than previous plants or the woody coniferous types occurring in later ages. Also, the coal field (Richmond Basin) sometime after its formation has been subjected to high temperatures possibly accompanied by high pressure (Eby, 1944), as is evidenced by the presence of natural coke in the coal seams. These extreme conditions that must have existed may have caused a change in the basic structure of the coal to increase the chemical activity of its constituents.

Continuance of Research.—The research on the hydrogenation of the Midlothian coal is being continued at the Virginia Polytechnic Institute using higher pressures and additional catalysts, in an effort to collect and correlate basic data necessary for the use in considering this coal as a raw material for liquid petroleum production when the synthetic liquid fuel industry becomes a commercial reality in this country.

LITERATURE CITED

AKABORI, S. AND T. SUZUKI 1929—The catalytic transfer of hydrogen between organic compounds. *C. A.*, 23: 4671; *Proc. Imp. Acad.* (Japan), 5: 255-256.

ASBURY, R. S. 1934—Action of solvents on coal. *Ind. Eng. Chm.*, 26: 1301-1304.

———— 1936—Action of solvents on coal. *Ind. Eng. Chem.*, 28: 687-90.

BERGIUS, F. 1926—The transformation of coal into oils by hydrogenation. *Proc. Internat. Conf. on Bit. Coal,* Carnegie Inst. of Technology, Pittsburgh, Pa., pp. 102-131.

BERL, E. H. BIEBESHEIMER, AND W. KOERBER 1941—Coal hydrogenation. *Ind. Eng. Chem.*, 33: 672-674.

BEUSCHLEIN, W. L. AND C. C. WRIGHT 1932—Hydrogenation of American coals. *Ind. Eng. Chem.*, 24: 1010-1012.

———— 1933—Hydrogenation of American coals in anthracene. *Ind. Eng. Chem.*, 25: 409-410.

BEUSCHLEIN, W. L. AND B. E. CHRISTENSEN 1932—Hydrogenation of American coals. *Ind. Eng. Chem.*, 24: 747-748.

BEUSCHLEIN, W. L. AND C. M. WILLIAMS 1934—Hydrogenation of American coals in diphenyl. *Ind. Eng. Chem.*, 26: 465-466.

BIGGS, B. S. AND J. F. WEITER 1937—Chemical constitution of bituminous coal as determined by its hydrogenation products. *Journ. Amer. Chem. Soc.*, 59: 369-371.

BOGNAR, H. 1937—Hydrogenation of coal in the presence of various solvents. *C. A.*, 31: 3237; *Magyar Chem. Folyirat,* 42: 162-168 (1936).

BOOMER, E. H., A. W. SADDINGTON, AND J. EDWARDS 1935—The hydrogenation of Alberta coals. *Con. Journ. Research,* 12: 825-839; *C. A.* 29: 5629.

DOLDI, S. 1939—The hydrogenating powers of the hydronaphthalenes. *Atti x° Cong. Int. Chim.*, 3: 633-639; *C. A.*, 33: 8599.

EBY, J. B. AND M. R. CAMPBELL 1944—Virginia coal fields, analysis of Virginia coals. *U. S. Bureau of Mines Tech. Paper* 656: 5.

FIELDNER, A. C., H. H. STORCH, AND L. L. HIRST 1944—Research on the hydrogenation of coals and lignite. *U. S. Bureau of Mines Tech. Paper* 666.

FEIN, M. L., ET AL. 1939—Solubility of tars and pitches from coal hydrogenation. *Ind. Eng. Chem. Anal. Ed.*, 11: 422-428.

FISHER, C. H. 1938—Relation between volatile matter and hydrogen-carbon ratio of coal and its banded constituents. *Ind. Eng. Chem. Anal. Ed.*, 10: 374-378.

FISHER, C. H. AND A. EISNER 1937—Primary liquefaction of coal by

hydrogenation. *Ind. Eng. Chem.* 29: 939-945.

FISHER, C. H. ET AL. 1939—Attrial matter and anthraxylon. *Ind. Eng. Chem.*, 31: 1155-1161.

———— 1942—Hydrogenation and liquefaction of coal, Part II. The effect of petrographic composition and rank of coal. *U. S. Bureau of Mines Tech. Paper* 642.

GENET, G. R. F. 1947—High pressure hydrogenation of Midlothian coal. Part I. *Unpublished M.S. Thesis.* Library, Va. Polytechnic Inst., Blacksburg, Va., pp. 94-95.

HIRST, L. L. ET AL. 1941—The hydrogenation of high volatile bituminous coals. *Ind. Eng. Chem.*, 33: 1068-1072.

———— 1939—Liquid phase hydrogenation of Pittsburgh Seam coal. *Ind. Eng. Chem.*, 31: 869-877.

HYDROGENATION OF COAL, Round-Table Discussion. 1944—*Ind. Eng. Chem.*, 36: 291-298.

JENNY, M. F. 1949—High pressure hydrogenation of Midlothian coal. Part II. *Unpublished M.S. Thesis.* Library, Va. Poly. Inst., Blacksburg, Va., pp. 67-68.

KASTENS, M. L. 1949—Liquid fuel from coal. *Ind. Eng. Chem.*, 41:870.

KIEBLER, M. W. 1940—Extraction of a bituminous coal. *Ind. Eng. Chem.*, 32: 1389-1394.

LOWRY, H. H. 1934a—Some chemical aspects of coal utilization. *Reprinted, Trans. Amer. Inst. Chem. Engrs.*, 30: 280-297.

———— 1934b—Thermal decomposition of coal hydrocarbons. *Ind. Eng. Chem.*, 26: 321-325.

POTTS, A AND H. BROCHE 1933—Action of tetralin as solvent in donating and transferring hydrogen. *Glukauf*, 69: 903; *C. A.*, 27: 2564.

SCHROEDER, W. C. 1943—Statement before Sub-committee on Public Lands and Surverys. *U. S. Senate Hearings, Pittsburgh, Pa.*, Aug. 6, 1943.

SCOTT, H. A. 1947—The low pressure hydrogenation of Midlothian coal. *Unpublished M.S. Thesis.* Library, Va. Poly. Inst., Blacksburg, Va., pp. 76-77.

SOLLIDAY, A. L. 1949—When do we need a synthetic fuel industry? *Oil and Gas Journ.*, 48: 24, 86-88.

SPRUNK, G. C. AND R. THIESSEN 1935—Relation of microscopic composition of coal to chemical coking and by-product properties. *Ind. Eng. Chem.*, 27: 446-448.

STORCH, H. H. 1935—Activity and activation energy in heterogeneous catalysis of gas reactions. *Journ. Amer. Chem. Soc.*, 57: 1395-1398.

———— 1937a—Coal Hydrogenation-Chemistry. *Ind. Eng. Chem.*, 29: 1367-1371.

———— 1937b—U. S. Bureau of Mines Experimental

Plant. *Ind. Eng. Chem.*, 29: 1377-1380.

STORCH, H. H. ET AL. 1943—Hydrogenation and liquefaction of coal. Part IV. Effect of temperature, catalyst, and rank of coal on rates of coal hydrogenation reactions. *U. S. Bureau of Mines Tech. Paper* 654.

———— 1945—Catalysis in synthetic liquid fuel processes. *Ind. Eng.Chem.*, 37: 340-351.

THIESSEN, R. AND G. C. SPRUNK 1935—Microscopic and petrographic studies of certain American coals.. *U. S. Bureau of Mines Tech. Paper* 564.

———— 1937—Origin and petrographic composition of the Lower Sunnyside Coals of Utah. *U. S. Bureau of Mines Tech. Paper* 573.

TUPHOLME, C. H. S. 1936—Hydrogenation of coal in Billingham. *Chem. Ind.*, 38: 29-36.

WARREN T. E. AND R. E. GILMORE 1937—Hygrogenation tests on Canadian coals. *Ind. Eng. Chem.*, 29: 353-358.

WARREN, T. E. AND K. W. BOWLES 1939—Hydrogenation tests on Canadian coals. *Ind. Eng. Chem.*, 31: 415-419.

News and Notes

(Editor's note: News contributions should be sent to the person whose name appears at the end of the appropriate section.)

The current issue of the Virginia Journal of Science constitutes the first number of the first volume of a New Series. Because of the fact that Volume III of the Old Series was never completed, having been terminated with the publication of the seventh number of the volume, May, 1943, it was deemed advisable by the editorial staff to resume publication with Volume I of a New Series.

NEWS FROM THE PRESIDENT

Dr. Gustav A. Hedlund, formerly of the University of Virginia, represented the Virginia Academy of Science at the 1000th meeting of the Connecticut Academy of Arts and Sciences, at Yale University, Nov. 4, 1949.

Dr. Boyd Harshbarger, Academy president, represented the Academy at the following events: Virginia Teachers Association, Richmond, Nov. 4; the inauguration of the campaign for a new science building at Bridgewater College, Nov. 18; and the inauguration of Mr. G. Tyler Miller as president of Madison College. President Harshbarger has met with the chairmen of various Academy committees as well as with officers of many of the sections.

THE 1950 MEETING AT ROANOKE

The final program for the Twenty-Eighth meeting of the Virginia Academy of Science to be held in Roanoke, May 11, 12 and 13, 1950, will be published in the April 1950 *Virginia Journal of Science.*

Reprints of the 1950 program (from the April issue) will be distributed at the Roanoke meeting; consequently, the section secretaries *must* send their programs to the president not later than March 5. *This March 5 deadline must be met.*

Abstracts of the papers for the 1950 Proceedings will be limited to not more than 200 words. Longer papers will be considered for publication in the Journal.

The 1950 programs will carry a definite clock time for each presentation, instead of the papers being listed as 1, 2, 3, etc. Therefore, it is requested that the section secretaries make up their programs with sufficient clock time allotted for each paper, and for discussion. In this way each person attending the meeting can arrange his schedule to hear only the papers in which he is interested.—BOYD HARSHBARGER, VIRGINIA POLYTECHNIC INSTITUTE.

MEETING OF THE COUNCIL AND EDITORIAL BOARD

RICHMOND, NOVEMBER 4, 1949

The meeting, called by President Harshbarger, was held at the Medical College of Virginia, with the following members present: H. R. Hanmer, H. H. Hobbs, Jr., Ladley Husted, Guy W. Horsley, E. C. L. Miller, Sidney S. Negus, Walter S. Flory, Jr., Foley F. Smith, and Boyd Harshbarger.

Plans for the 1950 meeting at Roanoke were discussed. The Virginia Junior Academy of Science will be entertained at an open house at Roanoke College on Thursday afternoon. A dinner will be held at Roanoke College that evening for participants in the Science Talent Search and Science Exhibit Contest. Senior members are urged to attend this dinner, but a charge of $1.50 will be made to them. Hollins College will entertain the Senior Academy at a tea on Friday afternoon. Friday and Saturday meetings of the Academy will be held at the Hotel Roanoke.

It was proposed and approved that the Research Fund reimburse the General Fund the sum of $100 for printing the Horsley Award certificates.

Dr. Hobbs reported on the progress of the *Virginia Journal of Science* and described the appearance and plan for the cover and general design of the magazine. It was decided that $2 for each member's dues be allotted for the magazine for 1949-50, and surplus would be returned to the general fund. On this basis the editorial board's estimate for one year of *Journal* publication was approved.

The *Radford News Journal* was awarded the contract for printing the *Virginia Journal of Science*, at $3.50 per page for 1,500 copies per issue. Dr. Husted discussed the question of exchange rights of the *Journal*, and stated that the Alderman Library at the University of Virginia had offered $300 for the exchange rights to the *Journal* on the basis of 125 copies, 25 of which would be used for the International Library. This offer was accepted.

The question of advertising rates in the *Journal* was discussed, and it was decided that the rates would be $30 per page per issue and $20 per half-page. Advertising will be limited to six full pages per issue, with none on either the inside or outside cover.

Clinton Baber, Larus Brothers and Company, Inc., was proposed as the *Journal's* advertising manager.

Dr. Harshbarger, Dr. Husted, and Dr. Hobbs were given a vote of thanks for their excellent work in re-establishing the *Virginia Journal of Science*.—FOLEY F. SMITH, RICHMOND.

TENTATIVE PROGRAM FOR 1950 MEETING OF THE VIRGINIA ACADEMY OF SCIENCE ROANOKE, MAY 10-13

WEDNESDAY, MAY 10, ROANOKE COLLEGE, SALEM, VIRGINIA

3:00 P. M.—Registration at the College for Junior Academy members and participants in the Science Talent Search

THURSDAY, MAY 11, ROANOKE COLLEGE, SALEM, VIRGINIA

8:00 A. M. to 9:00 P. M.—Registration at the College for Junior and Senior Scientists and Guests

10:30 A. M.—Participants in the Science Talent Search meet with P. C. Scherer

10:30 A. M.—Participants in the Science Exhibit Contest meet with F. S. Andrews and B. N. Cooper

11:00 A. M. to 4:30 P. M.—Judging of those entering the Science Talent Search and Science Exhibit Contests

1:00 to 6:00 P. M.—Registration of Senior Scientists at Hotel Roanoke for those not able to register at Roanoke College

2:00 P. M.—Annual Meeting of the Junior Academy of Science

3:00 P. M.—Meeting of the editors of the *Virginia Journal of Science*

4:00 P. M.—Meeting of the Council of the Senior Academy at the College

6:30 P. M.—Junior Academy Dinner at Roanoke College. Participants in the Science Talent Search and Science Exhibit Contest will be the guests of Roanoke College. Senior members are urged to attend this dinner but a nominal charge will be made.

8:30 P. M.—Program for the Junior members

8:30 P. M.—Academy conference and general meeting for Seniors at the College, President Boyd Harshbarger presiding.
Report of Committees

Roanoke College will hold Open House Thursday afternoon for Senior members

FRIDAY, MAY 12, THE ROANOKE HOTEL, ROANOKE, VIRGINIA

8:00 A. M.—Registration in the lobby

9:00 A. M.—Section Meetings

10:00 A. M.—Industrial Tour for Junior Academy members, subject to its being elected by a sufficient number of Juniors.

12:30 P. M.—Group Luncheons

2:00 to 4:00 P. M.—Section Meetings

4:00 P. M.—Section meetings adjourned. Junior and Senior members of the Academy to be guests at a reception at Hollins College in their honor.

7:30 P. M.—Academy Dinner at the Hotel Roanoke

SATURDAY, MAY 13, THE ROANOKE HOTEL, ROANOKE, VIRGINIA

9:00 A. M.—Section Meetings

10:00 A. M.—Council Meeting

2:00 P. M.—Field Trips

RESEARCH COMMITTEE

Encouragement of research in Virginia was one of the Academy's earliest aims. It was promulgated at the 1926 May meeting when President Loving appointed a committee for that purpose, composed of Doctors Horsley, Yoe and Shaw.

During the following year this objective began to approach reality with the creation of an endowment fund through personal subscription, and the organization of a "permanent committee on the encouragement of research in Virginia", both under the administration of President J. Shelton Horsley.

The committee made two recommendations which were favorably received and have been incorporated into permanent Academy policy:

1. The awarding of a $50.00 Academy prize for a particularly meritorious paper, based on research, and read before a section of the Academy at its annual meeting.
2. The making of grants-in-aid for worthy research projects in progress or contemplated by a member of the Academy.

Throughout the intervening years, the Research Committee has been charged with the responsibility of administering the income from the endowment fund, making the Academy Award and selecting recipients of the research grants-in-aid.

RESEARCH GRANTS-IN-AID

Grants are available each year to Academy members who submit to this committee worthy research problems for which financial aid is needed. Oftentimes, a grant made by the Academy is matched by the college or university at which the recipient is pursuing studies. Research grants during recent years have averaged between $75.00 and $100.00 each.

There are no forms to fill out. Simply outline the problem and list the items for which assistance is required. Names and addresses of three persons who know the applicant's qualifications for scientific research should be submitted with the request. Since funds are limited, applications should be mailed at an early date to H. R. Hanmer, P. O. Box 4178, Richmond 24, Virginia.

The Research Committee is particularly desirous of assisting younger members who qualify.

J. SHELTON HORSLEY RESEARCH AWARD

In 1946, without other change, the Academy prize was redesignated

as the "J. Shelton Horsley Research Award" in memory of the Academy's fourth president who did so much to stimulate the spirit of research in Virginia. The award has always been regarded as one of the most coveted prizes available to scientists in Virginia and the committee has felt that it should reflect a degree of scientific achievement commensurate with the high purpose for which it was instituted. At the same time, there has been an earnest desire to avoid undue restrictions.

Perhaps in an effort to preserve this high standard, many worthy papers have been automatically excluded, not by the committee nor from lack of interest, but rather because of the authors' extreme modesty. Whatever the reason, the extent of participation in recent contests has been limited to a comparatively few papers.

The committee, therefore, with the approval of Officers and Council, is inaugurating a different procedure for 1950. Every paper comprising a report of original research performed by its author, which is presented before any section of the Academy during the 1950 May session, will be eligible for the Award.

The Research Committee is soliciting the cooperation of the Officers of each Section, who will be asked to expedite the submission of papers. A letter will be addressed to them in the near future, giving details of the plan.

To the authors, the committee would offer only one word of counsel —brevity. It is suggested that papers be prepared in a form which would be acceptable for publication in the leading scientific journals.
—H. R. HANMER, AMERICAN TOBACCO COMPANY, RICHMOND.

THE JAMES RIVER PROJECT

Publication of the monograph of *The James River Basin — Past, Present, Future* has been promised for January 1950. Publication is under the supervision of Charles Lewis, state printer, Division of Printing and Publishing, and Clyde Saunders and Sons, Richmond, received the contract for the printing.
—MARCELLUS H. STOW, WASHINGTON AND LEE UNIVERSITY.

SCIENCE TALENT SEARCH COMMITTEE

Examinations for the National Science Talent Search were given in December. These, with essays and scholastic records, play an important part in the selection of the fifty state finalists of the Virginia Science Talent Search.

In order to encourage participation in this contest and in the Virginia Science Talent Search, the universities and colleges of Virginia are offering scholarships to be awarded to the finalists as follows:

COLLEGE	NO. OF SCHOLARSHIPS	AMOUNT	REMARKS
Averett	2	$100	Finalists
Bridgewater	5	250	15 Winners
	5	150	Finalists
Emory & Henry College	several	150	Finalists
		may be 400	
Fairfax Hall Jr. College	1	100	Finalists
Lynchburg College	1	200	Finalists
Mary Baldwin College	1	200	Finalists
Medical College of Virginia	1	300	Finalists—for study of pharmacy
Randolph-Macon College	1	200	15 Winners
	1	150	Finalists
Shenandoah College	2	100	Finalists
Southern Seminary	1	100	Finalists
Sweet Briar College	6	$100-700 (according to need)	Require College Entrance Board Exam.
University of Virginia	2	250	Finalists
Virginia Intermont	4	150	15 Winners
	6	100	Finalists
Virginia Military Inst.	several	indefinite	Finalists
Virginia Polytechnic Institute	6	165	Finalists
Virginia State College	2	100	Finalists
Washington & Lee University	2	225	Finalists

In addition to those scholarships listed above, Mary Washington College will offer needed assistance to any of the finalists who wish to attend that institution.

William and Mary College offers six science scholarships each year on the basis of its own science contest. The recommendation of a good showing in the Virginia State Talent Search will carry considerable weight in the awarding of these scholarships.—P. C. SCHERER, VIRGINIA POLYTECHNIC INSTITUTE.

JUNIOR ACADEMY OF SCIENCE COMMITTEE

Plans have been made to hold Science Open Houses in various districts of the state. The dates and places for these open houses have been tentatively arranged as follows:

Medical College of Virginia, Richmond, Virginia, March 31, 1950
Dr. F. P. Pitts, Chairman

William and Mary College, Williamsburg, Virginia, April 2, 1950
Dr. O. F. Schuette, Jr., Chairman

Bridgewater College, Bridgewater, Virginia, March 31, 1950, in cooperation with Madison College, Mary Baldwin, and Eastern Mennonite School, Dr. Harry Jopson, Chairman

Virginia Polytechnic Institute, Blacksburg, Virginia, April 21, 1950, in connection with the annual High School day, Dr. P. C. Scherer, Chairman

University of Virginia, Charlottesville, Virginia, date not confirmed, Dr. Raymond Bice, Chairman

University of Richmand, Richmond, Virginia, date not confirmed, Chairman to be appointed.

The Open House for colored students will be held at Saint Pauls School, Lawrenceville, Virginia, date to be determined.

Science Club Sponsors are requested to watch the High School Calendar for changes in the dates of the open houses and for the dates of the open houses not yet determined.

Sponsors of science clubs should send in their application for membership without further delay. A number of these applications have been received. These applications may be sent to Dr. Flood S. Andrews or B. N. Cooper, Virginia Polytechnic Institute, Blacksburg, Virginia.

You are reminded that science speakers are available to visit your club without cost to discuss subjects of interest to your science students. Write to F. C. Vilbrandt, Virginia Polytechnic Institute.—B. N. COOPER or F. S. ANDREWS, Virginia Polytechnic Institute.

LOCAL ARRANGEMENTS COMMITTEE

The Committee was organized in June 1949, and its chairmen formulated certain general policies with President Harshbarger at that time. Its first full meeting was held at Hotel Roanoke on Nov. 2.

The Junior Academy of Science and Science Talent Search will hold all of their activities at Roanoke College during the 1950 meeting. The visitors will be housed for the nights of May 10 and 11 without charge at the College or in nearby homes. The annual dinner of the Junior Academy will be furnished gratis by Roanoke College in its dining hall. One or more tours will be provided Friday afternoon, May 12, for junior members who wish to stay over to participate.

The Senior Academy will hold all of its meetings at Hotel Roanoke except for the annual business meeting, Thursday evening, May 11, which will be held at Roanoke College. Senior members so desiring may meet with the Junior Academy at their annual dinner, Thursday evening, just prior to the senior business meeting. There will be a meal charge for senior members. Section meetings will be held at Hotel Roanoke, Friday morning and afternoon and again on Saturday morning. A reception will be given Academy members and their families by Hollins College on its campus late Friday afternoon, and the annual

dinner will be held at Hotel Roanoke, Friday evening.

This Committee is as follows:

Chairman: P. M. Patterson
Co-chairman: Ashley Robey
Section rooms and projection equipment : John D. Schumacher
Registration: (Senior), Harriett H. Fillinger and Herta Taussig; (Junior) T. H. Gibson
Tours: (Junior), D. R. Carpenter
Housing: (Senior), C. Lucien Crockett; (Junior) Nellie Manges, Mrs. J. F. Prufer, R. Rush Anderson, and James W. Price
Public Relations: Kenneth Hood
Exhibits: (Senior), Helen Churchill and C. H. Raynor; (Junior), C. H. Raynor
Annual Dinners: (Senior), Cecile Finley; (Junior), T. C. Capraro
Guest Speakers: D. R. Carpenter
Reception: Louise Maddrey
Fifth Virginia Science Talent Search: Molly T. Denton
Junior Academy, Coordinator for arrangements: T. C. Capraro

—P. M. PATTERSON, HOLLINS COLLEGE.

FOREIGN STUDENTS EXCHANGE COMMITTEE

The *Directory of Higher Education* of the United States Office of Education lists 45 institutions of higher learning in Virginia. Significant statistics concerning the foreign students in these institutions are as follows:

Type of Institution	*Number in Va.*	*Having Foreign Students*	*Foreign Students*		
			Men	*Women*	*Total*
Colleges and Universities	22	15	88	44	132
Professional and Technological Schools	9	7	14	5	19
Teachers Colleges & Normal Schools	2	1	—	1	1
Junior Colleges	12	7	1	24	25
TOTALS	45	30	103	74	177

These 177 students come from 43 different countries, as follows:

Canada 28; China 28; Cuba 16; Liberia 9; British W. Indies 8; Nigeria 7; Sierra Leone 7; Venezuela 7; France 5; Panama 5; Germany 4; United Kingdom 4; Columbia, India, Netherlands, Philippines, and Poland 3 each; Argentina, Brazil, Costa Rica, Dominican Republic, Greece, Guatemala, Korea, and Union of South Africa 2 each; Chile, Cyprus, Czechoslovakia, Ecuador, Egypt, Iraq, Ireland, Italy, Lebanon, Malaya, Mexico,

Nicaragua, Norway, Peru, Rhodesia, Spain, Sweden and Turkey 1 each.

For purposes of comparison with other states in the South, the number of foreign students in the academic year, 1948-1950, is as follows:

State	*Total*	*In the Univ. of*	
Alabama	112	Ala.	18
Arkansas	56	Ark.	10
Florida	230	Fla.	53
Georgia	286	Ga.	15
Kentucky	158	Ky.	31
Louisiana	455	La.	281 (incl. A. and M. and Jr. Coll.)
Mississippi	67	Miss.	9
North Carolina	262	N. C.	113 (incl. Raleigh and Greensboro)
South Carolina	83	S. C.	3
Tennessee	215	Tenn.	55 (Knoxville and Memphis)
Texas	653	Texas	246
Virginia	177	Va.	20 (incl. Mary Washington)
West Virginia	44	W. Va.	11

The number of foreign students, men and women, in each of the individual institutions of the state is available, if anyone is interested in the details. —EDGAR J. FISHER, SWEET BRIAR.

THE SPEAKERS BUREAU

Many Virginians in educational, industrial, and extension activities have indicated their willingness to co-operate wholeheartedly in the programs of the Virginia Junior Academy of Science, Science Clubs, and science classes in the high schools, which are interested in science and which are interested in hearing professional men and women speak on their particular activities and interests.

The principal of the high school, the sponsor of the Science Club, or a teacher, may contact the director of this Speakers' Bureau, requesting the choice of subject or speaker, giving the dates and hours when the speaker is needed. In addition, the speakers are making themselves available to speak before high school assemblies. The speakers are willing to extend help to young boys and girls and to maintain close association with and participation in the educational activities of the community in which the speakers live. It is a sincere hope that the ties between the individual speakers and the high school students will result in an activation of the science talent latent in the boys and girls, who later may become active participants in the programs of the National and Virginia Science Talent Search.

A request letter directed to the Speakers' Bureau requesting the above help will start the ball rolling. The high school principals, the

sponsors of Science, the director of the Speakers' Bureau, and the speakers will fall in line. The Speakers' Bureau will attend to correspondence, and making arrangements with the speakers. The service and the speakers are furnished free of all costs.

In most cases, the speaker will be able to come at the time which is designated, but as a matter of courtesy, it will be necessary for him to have ample time to make proper arrangements for the visit.

—FRANK C. VILBRANDT, VIRGINIA POLYTECHNIC INSTITUTE

VIRGINIA FLORA COMMITTEE

Professor R. S. Freer, Lynchburg College, has completed a manuscript based on his botanical work in the central Blue Ridge Mountains in Virginia.

Plans are being made for a botany field trip on Saturday of the 1950 Academy meeting. Mr. A. R. Cochran, supervisor of the Jefferson National Forest, took Professor A. B. Massey, Virginia Polytechnic Institute, over the route of a proposed trip in the Blue Ridge Mountains starting near Buchanan, and windiing up at Cave Mountain near National Bridge Station where the group will have a weiner roast. A fee will be collected to cover the cost of the roast. Transportation will be arranged by those participating.—A. B. MASSEY, VIRGINIA POLYTECHNIC INSTITUTE.

SECTION NEWS

ARGRICULTURAL SCIENCE SECTION

The Virginia Polytechnic Institute Agronomy Department and outlying research stations are placing special emphasis on pasture research. A new pasture research station has been established near Middleburg, Virginia.

Research in disease control through the development and use of disease-resistant varieties of agricultural crops is being conducted by the newly established Department of Plant Pathology and Physiology, with Dr. S. A. Wingard as head, at Virginia Polytechnic Institute. Diseases which attack the following crops are being studied: alfalfa, red clover, peanuts, corn, small grains, beans, raspberries, blackberries, grapes, and tomatoes.

Dr. G. M. Shear, Virginia Polytechnic Institute plant physiologist, and Dr. L. L. Danielson, physiologist for the Virginia Truck Experiment Station, at Norfolk, are doing research on the effects of chemical weed killers on various crops. Dr. Shear's work applies to lawns, pastures, and field crops. Dr. Danielson's work applies to truck crops. Both report considerable progress.

Dr. James H. Bywaters and associates, of the Virginia Polytechnic Institute Poultry Department, are working on a long-time project to

test the theory that inbred lines of standard-bred chickens can be developed which will be as good or better than any of the hybrids now in use or contemplated.

Three years of exploratory field studies, mainly to formulate methods and procedures for investigating some of the more urgent problems on the use of irrigation, have been made by agricultural engineers at Virginia Polytechnic Institute. C. E. Seitz, head of the department says that this project was revised in 1949 to include a pasture irrigation study and a control plot irrigation study with the following crops: corn, small grains, clover, alfalfa, and burley tobacco.

The field work on a cooperative regional study of spoilage in marketing of early Irish potatoes has been concluded. The Virginia Polytechnic Institute cooperated.

All Agricultural Science Section papers should be in the Section secretary's hands by March 1, 1950. Abstracts will not exceed 200 words. Send them to M. M. Parker, P. O. Box 2160, Norfolk.—T. J. NUGENT, Box 2160, NORFOLK.

ASTRONOMY, MATHEMATICS AND PHYSICS SECTION

Dr. Frank L. Hereford, who has been with the Bartol Research Foundation for the past two years, has returned to the Physics Department of the University of Virginia.

Virginia Polytechnic Institute is now a member of the southeastern institutions which sponsor the Oak Ridge Institute of Nuclear Studies.

Dr. E. J. McShane, mathematician at the University of Virginia, is attending the Institute for Advanced Studies.

Dr. Forrest F. Cleveland, formerly at Lynchburg College and now at the Illinois Institute of Technology, presented six papers at the annual meeting of the American Physical Society.

The Physics Symposium sponsored jointly by the Oak Ridge Institute of Nuclear Studies and the Oak Ridge National Laboratory was held at Oak Ridge during the summer of 1949. It is proposed to make this meeting an annual affair, with the 1950 symposium devoted to chemistry. Those who attended the 1949 meeting from Virginia were: J. W. Moore, Medical College of Virginia; I. G. Foster, Virginia Military Institute; and Webster Richardson of Virginia Polytechnic Institute.

Major J. B. Newman, who has been studying in the Cornell University graduate school for the past four years, has rejoined the physics staff of Virginia Military Institute.

Dr. Jesse W. Beams, physicist at the University of Virginia, was elected vice-president of the Oak Ridge Institute of Nuclear Studies last spring.

The recent and untimely death of Dr. W. J. Humphreys, meteorologist and physicist, brought to an end the career of one of Virginia's

best-known scientists. He was a native of West Virginia, and was educated at Washington and Lee, the University of Virginia, and Johns Hopkins University. He was an instructor for several years at the Miller School and at the University of Virginia. He received many honors during his lifetime and was the author of the classic "Physics of the Air."

For the first time Virginia Military Institute is now offering a major in physics.—IRVING G. FOSTER, VIRGINIA MILITARY INSTITUTE.

BACTERIOLOGY SECTION

The Virginia Branch of the Society of American Bacteriologists, which is affiliated with the Virginia Academy of Science, held its semi-annual meeting in Richmond, Nov. 19. The following papers were presented:

"Cultivation Studies on *Endamoeba histolytica*."
E. C. Nelson, Medical College of Virginia.

"The Culturing of Gonococci from Male Patients."
A. L. Rosensweig, Veterans Administration Hospital, Richmond.

"The Examination of the Air in a Crowded Gymnasium for the Viruses of Influenza and Herpes Simplex."
Barbara H. Caminita and J. E. Faber, Jr., University of Maryland.

"Possible Occurrences of a Variant of *Proteus mirabilis* in Chinchillas."
J. M. Sharpley, University of Richmond.

"Some Experiments in the Determination of Nitrate Nitrogen in Water."
Travis Hill, Virginia State Department of Health Laboratories, Richmond.

A report on the recent Symposium on Brucelloxis held at the National Institute of Health, Bethesda, Maryland.
W. A. Dorsey, Richmond City Bureau of Health Laboratory.

—J. DOUGLAS REID, RFD 13, RICHMOND.

BIOLOGY SECTION

Miss Cate Johnson has come from the University of Tennessee to assume teaching duties at Hollins College. Miss Johnson's field of interest is parasitology.

Mr. James N. Dent and Mr. Edwin W. Pullen have been added to the staff of the Miller School of Biology, University of Virginia. Mr. Dent, acting associate professor of biology, is a graduate of the University of Tennessee. He received the Ph.D. degree from Johns Hopkins University and before coming to Virginia taught at Marquette University and the University of Pittsburg. His research interest is in the fields of comparative anatomy and experimental embryology. Mr. Pullen,

instructor in physiological histology, received the B.A. degree from Colgate University and the M.S. from the University of Massachusetts. He is primarily interested in histological research.

A new department of plant pathology and physiology, with Mr. Samuel A. Wingard as head, has been formed at the Virginia Polytechnic Institute. Courses will be taught by Mr. Wingard, Mr. G. M. Shear, Mr. R. G. Henderson, Mr. C. W. Roane, Mr. S. B. Fenne and Mr. John Amos. The experiment station is expected to eventually employ a new man to take over the time that the former full-time station members will devote to part-time teaching.

The Mary Baldwin College board of trustees at its fall meeting in October authorized the conversion of Frazier Hall into a biology building. Plans for the new quarters call for two large laboratories, one lecture room, several small laboratories, an animal room, dark room, and storage space.

The Biology Department of Lynchburg College moved into new and larger quarters during 1948. New equipment for audio-visual work has been added.

Mr. John G. Mahan, formerly at the University of the South, has become a member of the staff of Lynchburg College. Mr. Warwick R. West, at Lynchburg College for the past three years, is on leave of absence for graduate study at the University of Virginia.

Mr. Chauncey McLean Gilbert, a member of the Virginia Academy of Science, died October 2, 1949, at his home in Charlottesville after a prolonged illness. Mr. Gilbert was born in Troy, New York on April 6, 1882. He attended Troy Academy, Phillips Exeter Academy, and Massachusetts State College where he received the B.S. degree. After teaching for some years in Massachusetts he became a member of the community of biologists at Charlottesville where he earned the Ph.D. degree and a place on the teaching staff of the University of Virginia.

Mr. Gilbert was the author of several scientific papers and his monograph, "A Comparative study of three new American species of the genus *Phaenocora* with special reference to their reproductive organs and their relationship with the described forms of the genus," is considered to be the best morphological paper on rhabdocoels to have come from the Miller School of Biology. He was known for his excellence as a teacher of comparative anatomy, embryology and physiological histology. He demanded that he and his students exercise exactness, industry, integrity and intelligence. He will be fondly remembered by those fortunate enough to have had a place in his laboratory.

Mr. Gilbert is survived by Mrs. Gilbert and two sons, Chauncey McLean and Charles Alsop Richard. The University and the State gained when Mr. Gilbert chose to make his home here. His loss will be long-felt.—LADLEY HUSTED, UNIVERSITY OF VIRGINIA.

CHEMISTRY SECTION

Abstracts of papers for the 1950 meeting should be in the hands of the Section Secretary, J. Robert Taylor, American Viscose Corporation, Roanoke, by March 1.

News of this section is ably covered by *The Bulletin* of the Virginia Sections of the American Chemical Society and *The Blue Ridge Chemist*. This first issue of the chemists' page contains a few items illustrative of the varied contributions of our members.

Prof. John H. Yoe, University of Virginia, attended the fifteenth biennial conference of the International Union of Chemistry, held in Amsterdam in September. Dr. Yoe is a member of the international commission on new analytical reagents.

Dr. Allan T. Gwathmey, University of Virginia, and Dr. Henry Leidheiser, Jr., now of the Virginia Institute of Scientific Research, received the Science Research Award of the Oak Ridge Institute of Nuclear Studies in September. Dr. Gwathmey also received the Algernon Sydney Sullivan award in June for his outstanding services to the University.

Papers at the September meeting of the Americal Chemical Society included the following presented by Virginians:

Hartwell F. Calcote, Charles M. Barnett, and Moreland R. Irby, Experiment Incorporated, "Burning Velocity of Various Compounds by the Bunsen Burner Method."

Robert E. Lutz and J. S. Gillespie, Jr., University of Virginia, "Aluminum Isopropoxide and Lythium Aluminum Hydride Reductions of Unsaturated 1,4-Diketones."

W. E. Roseveare, E. I. DuPont de Nemours, Richmond, "Heat Degradation of Cellulose."

Dr. C. W. Tait, also from DuPont, discussed "The Physical Characterization of Cellulose Xanthate in Solution" at the Gordon Conferences at New London, Connecticut during the summer. Drs. C. L. Lawrence and C. M. Thacker, of the Solvay Process Division, in Hopewell, attended conference on "Catalysis" and "Petroleum," respectively.

Dr. E. A. Tippetts presented a paper at the September meeting of the T.A.P.P.I. in Portland on "The Potential of Cellulose as a Chemical Raw Material."

A Research Department, correlating the research of the six divisions of the Virginia-Carolina Chemical Corporation, was established in Richmond on July 1, with R. B. Arnold as Director and William P. Boyer as Assistant Director. Other members of the staff brought to Richmond include George Boyd, Charlotte Hale, and Herschel Jenkins.

—WILLIAM TROUT, JR., BOX 64, UNIVERSITY OF RICHMOND.

EDUCATION SECTION

Dr. Lindley J. Stiles, of Ohio State University, has succeeded Dr. John Manahan as dean of the department of Education of the University of Virginia. Dr. Manahan, who resigned after serving as dean for 29 years, will continue as professor of educational administration. Dr. Styles received his B.A., M.A., and E.Ed. degrees from the University of Colorado, and served for ten years in various teaching and administrative capacities in the public schools of Boulder, Colorado. Dr. Stiles has also served on the faculty of the College of William and Mary and as director of student teaching at the University of Illinois.

Atomic energy was the subject under discussion when the Elementary and Secondary Science Sections of the Virginia Education Association met in a combined meeting on November 4 during the VEA annual convention in Richmond. Addresses and discussions centered around the meaning of atomic energy in modern society, the materials to be utilized in the teaching of atomic energy, and the problem of teaching atomic energy in chemistry and physics, as well as in the elementary schools.

The State Board of Education has announced that 76 counties in Virginia have already adopted or are now in the process of converting to the 12-year school system. The additional year has been developed as an eighth grade, the first year of a five-year high school plan.

—FRANCIS G. LANKFORD, JR., PEABODY HALL, UNIVERSITY OF VIRGINIA.

ENGINEERING SECTION

The Virginia Polytechnic Institute chapter of Sigma Xi announced recently that the annual prize of $50 for the outstanding scientific thesis submitted to the graduate school has been awarded to Walter C. Gray of Roanoke, Virginia. The title of Mr. Gray's thesis is: "Effect of Ultrasonic Irradiation on an Ethyl Alcohol-Hygroden Peroxide-Water System."

—D. H. PLETTA, VIRGINIA POLYTECHNIC INSTITUTE

GEOLOGY SECTION

The State Geological Survey Division has moved into new and larger quarters in the new Geological Survey Building at the University of Virginia. New staff members include: Miss Jean Lowery, district geologist for Southwest Virginia; W. T. Harnsberger, fuels geologist; A. C. Walker, groundwater geologist; and H. C. Sunderman, economic geologist. Miss Lowery is stationed at Wytheville. Mr. Sunderman is completing work for his doctorate at the University of Wisconsin.

Brooks Museum has been remodeled, with more available space for laboratories, classrooms, and offices.

Dr. D. S. Robertson, Columbia University, has joined the School of Geology at the University of Virginia. A complete x-ray laboratory for

geological use has been installed.

During the summer an extensive program of field work was carried on by several students majoring in geology at various Virginia colleges. They were employed by the State Department of Highways to investigate the stone resources in several areas. This project was initiated and supervised by W. T. Parrott, the Department's geologist.

Dr. Marcellus H. Stow, head of Washington and Lee's geology department, has fully recovered his health after many months on the sick list, due to an earlier mistaken medical diagnosis.

Dr. W. D. Lowry has joined the geology staff as an associate professor at Virginia Polytechnic Institute.

Prospecting for mineral deposits and exploratory drilling for petroleum and natural gas continues in Virginia. Discoveries of commercial gas in Wise, Dickenson, and Buchanan counties are being made, but the eventual size of this development can not be estimated at present.

—B. N. COOPER, VIRGINIA POLYTECHNIC INSTITUTE.

PSYCHOLOGY SECTION

The Section Editor for the *Journal* requests that the psychologists of the State throw their support behind the newly revived *Virginia Journal of Science* as wholeheartedly and effectively as possible. This support should take the form of both financial contributions to the expenses of the *Journal,* and the submission of notes and manuscripts for publication. It is hoped that at least one article (or several brief notes) will appear in the psychology section of the Journal in each number.

Dr. Noble McEwen, Randolph-Macon College, and Dr. Elizabeth Moller, Sweet Briar College, have recently become members of the Psychology Section of the Academy.

John N. Buck, Section Chairman, represented the Psychology Section at the annual conference of State Psychological Associations, held in Denver in September in conjunction with the meetings of the American Psychological Association. The principal topic of discussion at the conference was the licensing of practicing psychologists.

On August 10 and 11 John N. Buck, Mrs. Catherine Giblette and Mrs. Mary Lively met in Richmond with Judge E. H. Williams (who as director of the Department of Professional and Occupational Registration is now Executive Secretary of the Examining Board for Clinical Psychologists) to rewrite the proposed licensing legislation in suitable form for presenting as a bill before the Legislature of 1950. As soon as the Attorney General has approved the draft it will be mimeographed and a copy sent to each member of the Section and all other interested persons. Section members are urged to request their Representatives and Senator to give the bill wholehearted support.

Paul G. Cheatham resigned as Secretary-Treasurer of the Section in September after having accepted a position on the faculty of Davidson College in North Carolina. Stanley B. Williams, William and Mary College, is the new Secretary-Treasurer. Abstracts and news notes should be sent to Dr. Williams, Department of Psychology, College of William and Mary, Williamsburg,

Lynchburg State Colony announces the appointment of Miss Patricia Nigg of Los Angeles to the position of Psychologist A to succeed Mrs. Catherine Whitehead, who went on leave of absence December 1.

Dr. John K. Bare, B.A. of Oberlin, and Ph.D. of Brown, 1947, is now an assistant professor at William and Mary. Dr. Bare is teaching experimental psychology and doing his best to expand the laboratory facilities.

The Williamsburg Area Guidance Clinic was opened in Williamsburg in September, under the general direction of the State Department of Mental Hygiene and Hospitals. The psychologist at the clinic is W. R. Reese who is also serving as acting director until a psychiatrist can be hired. Mr. Reese formerly was a child psychologist in the Child Study Department of the Akron, Ohio, Board of Education and also taught at Ohio State.

In 1949 an extensive remodeling operation was carried out at the University of Virginia psychological laboratory to provide additional research space. Prior to the remodeling there were four research rooms. Eleven have now been completed, and five additional rooms will be built during the winter months. Along with the new equipment recently acquired by the laboratory, this expansion has greatly improved the research facilities there.

Two former graduate students in the School of Psychology at Virginia returned to the University this past summer as members of the summer school faculty. They are Robert C. Wingfield of Converse College, who took his Ph.D. at Virginia, and James M. Porter of Rensselaer Polytechnic Institute, who holds a bachelor's and master's degree from Virginia. The summer school faculty in psychology was completed by William M. Hinton of Washington and Lee University.

Willard R. Thurlow, assistant professor of psychology at the University of Virginia, spent several weeks during the summer at the University of Rochester where he took part in a Navy research contract on the neurology of hearing.

Frank A. Geldard, chairman of the School of Psychology, is expected to return to the University of Virginia in February after a year's leave of absence. He has been chief civilian research psychologist in the Human Resources Division, Research and Development, Headquarters, U.S. Air Forces in Washington.

Two psychologists received their doctor's degrees from the University of Virginia in June. They were Paul G. Cheatham who is now an

assistant professor of psychology at Davidson College, and Eugene R. Long who holds a similar rank at the University of North Carolina. O. Ashton Trice, another graduate student of the last several years at Virginia, is now an assistant professor of psychology at Mary Baldwin College. Mr. Trice plans to continue with his research toward the doctor's degree at Virginia.

—RICHARD H. HENNEMAN, UNIVERSITY OF VIRGINIA.

SCIENCE TEACHERS SECTION

The first meeting of the Science Teachers Section was held at the 1949 Academy meeting. This new section was organized with the following temporary committee: L. W. Jarman and Miss Harriet D. Snow, Thomas Jefferson High School; Miss Esther Ruffin, St. Catherine's Episcopal School in Richmond; Mrs. Meade Ferguson, Highland Springs High School; and Dr. Sidney S. Negus, Medical College of Virginia, acting in an advisory capacity.

Eleven hundred questionnaires were mailed to all high school science teachers in Virginia, requesting program suggestions and other advice in interests of the new section.

W. I. Nickels, of Lane High School, Charlottesville, was named chairman-elect for the section; Mr. Jarman was elected chairman for 1949-50, and Mrs. Ruffin was continued as secretary.

The 1950 program will include illustrated lectures on certain fundamental concepts of physics and biology. All high school science teachers will be notified of the completed plans and program for the 1950 meeting in early spring.—B. W. JARMAN, 1216 LORRAINE AVE., RICHMOND, VA.

STATISTICS SECTION

The Virginia Polytechnic Institute has established a Department of Statistics in the School of Applied Science and Business Administration, and an associated Statistical Laboratory in the Agricultural Experiment Station. Boyd Harshbarger is head of the department; M. E. Terry, associate professor; Glenn W. Suter, Bureau of Agricultural Economics collaborator; and M. F. P. Nightingale, graduate assistant.

J. M. Sykes is now associated with the research division of the Southern Varnish Company; his new address is 2216 Brandon Avenue, S. W., Roanoke, Virginia.

E. L. Cox is now taking advanced work at the Institute of Statistics, Raleigh, North Carolina.

Rutledge Vining, who was in New York City last year with the National Bureau of Economic Research, is again with the University of Virginia.

The Statewide Grain Survey, under the guidance of the Division of Markets, the Virginia Crop Reporting Service, and the Statistical Laboratory of Virginia Polytechnic Institute has now been completed.

—M. E. TERRY, VIRGINIA POLYTECHNIC INSTITUTE.